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SYMPOSIUM
ON
INDUSTRIAL STATISTICS

14 OCT. 1955

**HELD IN ATIRA
IN DECEMBER 1954**

AHMEDABAD TEXTILE INDUSTRY'S RESEARCH ASSOCIATION

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FOREWORD

Statistical Quality Control (SQC) techniques are widely used in various industries abroad. As far as India is concerned the visit of Dr. Walter A. Shewhart of the Bell Telephone Laboratories, U.S.A. (the originator of SQC movement) to India during 1947-48 created a wide-spread interest in the subject.

Though other centres in India were alive to the problem, a systematic effort to promote the use of these techniques in industry was first made by ATIRA in 1949. During the last few years this technique has become extremely popular in the textile mills here. Later on a number of other industries at different centres in India made a beginning in the introduction of SQC techniques.

The Indian Statistical Institute, Calcutta, invited Dr. Walter A. Shewhart to visit India again and accordingly he came to India in October 1954 to visit centres actively engaged in SQC work. ATIRA felt that it would be extremely useful to arrange a symposium of Industrial Statistics to synchronise with the visit of Dr. Shewhart to Ahmedabad. This symposium was arranged with two objects in mind. The first was to give a report to Dr. Shewhart of the progress Ahmedabad Textile Industry has made by taking advantage of SQC techniques and the second was to place before him our difficulties so that we can get solutions by discussions with him. The programme was arranged in such a way that all the sections of textile industry would have an opportunity to meet Dr. Shewhart. The first session was arranged especially for the management to discuss organisational problems relating to SQC departments; the second session was arranged for the technicians to disccuss some interesting case histories and the last two sessions were arranged mainly for the statisticians to discuss the statistical techniques of interest to them. During each session some four or five papers were read by interested persons and this was followed by lively discussions. The proceedings were of great interest to all and at the request of various persons, ATIRA thought of publishing the proceedings of this symposium. It is hoped that these proceedings will serve a useful purpose.

Statistics Division,
ATIRA,
Ahmedabad-9.

V. N. Patankar

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Dr. Walter A. Shewhart, of the Bell Telephone Laboratories, U.S.A., inaugurated the Symposium on Industrial Statistics held in ATIRA on Friday, 31st December, 1954.

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SYMPOSIUM ON INDUSTRIAL STATISTICS

SESSION I

"Organisational Problems Relating to Statistical Quality Control Departments in Textile Industry"

[Held in ATIRA Auditorium on Friday, 31st December, 1954
Dr. Vikram A. Sarabhai, Director, ATIRA, in Chair]

INTRODUCTORY REMARKS BY DR. SARABHAI

The essence of statistical quality control techniques is to place before technicians, management and workers figures in a suitable form for taking necessary action. SQC techniques decide on the basis of the data collected how much of the variation in a given characteristic could be attributed to chance and how much to assignable causes. In an industry with hundreds of looms and thousands of spindles, mere master-craftsmanship is not sufficient and facts put in a systematic order help in taking decisions and actions. We therefore feel that statistical techniques must become an integral part of the working of a mill. Before five years, we had little knowledge of SQC but with the cooperation of management and technicians, SQC work has developed to the present stage.

I am posing three organisational problems before you for discussion. With the introduction of a statistical section in a mill, there arises a sense of suspicion amongst technicians about the statistician and ATIRA with whom he is associated. This is because of a sense of insecurity arising out of work of collecting data and reporting to the management done by a statistician. In the initial period, mishandling the situation, due to inexperience by ATIRA workers, lack of the knowledge of SQC techniques on the part of technicians and a lack of appreciation of the scope of the techniques by management created problems. It is therefore necessary to consider how best to integrate the section in the set up of a mill.

The second problem is whether we should have professional statisticians trained in technology or technicians trained in SQC techniques. ATIRA has tried to solve this problem to some extent by conducting courses on SQC for technicians to enable them to appreciate the work of SQC sections in their mills. These technicians have now formed the Quality Control Group which forms the backbone of the SQC movement in Ahmedabad.

The third problem is whether this training is to be confined to the technicians and management or is it going to reach the rank and file of the industry. We should then consider what measures would make it reach all levels.

THE SQC DEPARTMENT IN A TEXTILE MILL—HOW TO ORGANISE ONE AND MAKE IT WORK SUCCESSFULLY

Champaklal Nathalal

Agent, The New National Mills Ltd., Ahmedabad

I am very grateful to ATIRA for having given me this opportunity to put before you my views on how to set up an SQC department in a textile mill and get the most out of it. It is not necessary to deal with the subject exhaustively before such an audience. I shall therefore go over the broad principles only.

Statistical quality control methods were first developed by Dr. Walter A. Shewhart in U. S. A. They received special attention during the second world war when the American Government opened centres to popularise them.

Personnel for SQC Departments

The use of SQC techniques in industry in India can be traced to the forties. Courses of lectures were delivered and programmes drawn up to promote SQC methods. The visit of Dr. Walter A. Shewhart added great momentum to the movement. Here in Ahmedabad the creation of ATIRA with a separate statistics department under Dr. Vaswani was the starting point for the application of statistical methods to quality control. ATIRA has suggested the personnel required for the quality control department in a textile mill. It has also prescribed the academic qualifications for the personnel of the department. It is essential that the men in charge of these departments be highly intelligent and possess a good insight into things for they are continually engaged in a critical examination of the information in the form of data on the various characteristics collected by the investigators, in designing and conducting experiments for assessing various alternatives and in preparing reports on the basis of the above to help the management take suitable decisions. Besides they should be very skilful in dealing with people. A perfect relationship between them and the technicians and labour is an essential requisite for the smooth working of the department. Results achieved by them are rarely a direct product, but come from the action prompted in others by them. Their temperament needs to be such that they can examine day to day difficulties calmly and in the right perspective unaffected by the pressure of the moment. Enthusiasm and organising ability are also essential qualifications for the men in charge of these departments.

Training of Technicians in SQC

It has been found that the quality control staff and technicians do not agree on certain observations made by the staff. A practical solution to this is that there should be at least some people on this staff who have long practical experience. As Dr. Vaswani had once said we had better train technicians statistically rather than train statisticians technically. It would be unfair on my part if I fail to mention here that ATIRA has arranged lectures, in this connection, by Prof. Ekambaram and is sponsoring such activities with a view to making technicians statistically minded. But I would like to suggest to ATIRA that for the success of such pregammes the most important thing is the approach. They should adopt the T.W.I. approach. I mean they should not stop with just giving a fortnight of lectures to technicians but make the philosophy of statistical quality control infiltrate down to the rank of the ordinary worker. They should have follow-up courses and lectures and discussions conducted in the mills to infuse the idea into the minds of all. I think with this type of approach results would be more satisfactory and ATIRA would be able to extend their activities to the mills where quality control departments do not exist.

Some Suggestions for the Success of SQC

For the success of the department the management should also accord the head of this department the same status as other technical heads of departments. In other countries the quality control engineer enjoys a high standing in the organisational set up.

Coming to the measures to avoid the shortcomings of this department, first the active backing and support of the management is necessary to make it clear to all the sections of the organisation that they must co-operate and help the department, for quality requires the co-operation of everyone.

Management also should not expect quick results. It must have patience to allow the scheme to be introduced and extended gradually.

It should also be prepared to improve equipment when data collected from investigation etc., point out this to be necessary.

It should be recognised that statistical control is no magic in itself, and that benefits are derived by acting on the information provided by the department.

Enough well-informed staff should also be provided to organise and introduce the scheme.

Benefits of SQC

If the above measures are put into practice the result would be that production efficiency would be increased. Machines are stopped less often, less material and labour would be wasted. Final inspection would be also less owing to check at intermediate stages (which in a textile mill range from 20 to 25).

Indirect advantage of this will be that operatives look at a job from a new angle and improvements are almost bound to follow. Instead of thumb rule (or empirical) methods, scientific methods of inspection and control would be the order.

Finally, on account of the above, costs would be reduced, output increased and we will be able to produce quality products.

HOW I ORGANISED THE QUALITY CONTROL DEPARTMENT IN OUR MILL

S. M. Jaya Rao

Statistician, The Vikram Mills Ltd., Ahmedabad

This paper is based on my experience as a statistician attempting to introduce and make use of the statistical techniques in a textile mill.

Organisation

The statistical quality control department was started three years ago with a statistician and two investigators. The statistician was trained by Dr. S. P. Vaswani and her team of statisticians for a year by which time he was able to take independent charge. Today the department has the same statistician and six investigators, thanks to the management, who are closely in touch with the working of this department.

The functions of this department are threefold :

1. Collection and interpretation of data on a routine basis and maintaining control charts.
2. Initiating projects to explore new avenues for introducing quality control techniques and conducting experiments to assess the difference in working when some change is envisaged.
3. Suggesting improved methods of maintaining the records kept in various departments to make them more reliable and systematic and re-organising the stores department to control the consumption of the various items.

Collection of Data and Maintaining Control Charts

Data is collected daily on all important characteristics at each stage of the process. This has been found to be very useful in maintaining production, controlling the quality of the product and keeping the waste at the desired levels by reviewing the situation from time to time.

Control charts are being maintained with the help of this data on important characteristics at some stages of the process for the last two years with a view to assist the technicians in taking decisions about the process.

The experience in making use of these charts is a mixture of disappointment and success. The following factors appear to play an important part in using the control charts successfully and in making them occupy a prominent place in day to day working.

(a) Deciding the proper characteristics which are important in the view of the technicians and incidently of the management to maintain control charts.

Control charts were started on full lap weight in blow room, wrappings in drawing and end breaks in ring spinning. The object of these charts was explained to the technicians to whom the idea was new and it took some months before they could get into a spirit of co-operation to follow the charts. By this time the mixing on which we were maintaining control charts was stopped by the management due to market conditions. This meant starting all over again with collection of data for some other mixing and maintaining fresh charts. This I could have avoided if I had not erred in my judgement as it would have been possible to take a mixing which was stable by consulting the salesman or the management. Control charts were started on a stable mixing and the following examples are taken from the actual working of these charts.

The number of laps falling beyond tolerance limits was very high in blow room. After starting the control charts, the natural limits of variation were estimated from the charts. The spinning master revised his tolerance limits from ± 8 ozs. to ± 14 ozs. on the basis of this chart. He started taking corrective action to reduce variation. The charts were continued and the natural limits were assessed from time to time and variation and trend were studied. It was also possible to reduce the limits of variation from ± 14 ozs. to ± 10 ozs. on some scutchers and to ± 8 ozs. on others with less laps falling out of limits. (Incidently, in one of the mills in Mysore, when the quality control charts were introduced first in the blow room which was newly erected it was possible to show that their process average was far below the standard specified. This was traced to a belt which was not of the original make).

At this stage, when technicians and management were able to appreciate the advantage of these charts, the management felt that much valuable work could be done if charts were maintained on damage of cloth for export instead of end breaks.

Thus a year was spent in deciding upon the characteristics which are important for maintaining control charts. However, this period was useful in so far as it enabled the technicians to appreciate the use of these techniques.

One is often faced with situations where the appropriateness of choosing a particular characteristic is questioned after some time on technical grounds.

(b) Support of Management, Technicians and Labour :

While a stage is reached when technicians are convinced of the efficiency and reliability of the charts and are taking corrective action on the basis of the charts, it is found that at times they are not able to take action or set right the situation due to operative or management not viewing the situation with seriousness.

Instances of opposite nature are also not few. The management realised the advantage of the charts and insisted on the heads of the departments concerned to utilise them. The characteristics on which control charts were required were discussed with the heads of departments and charts were placed in their offices. After two weeks, I took a round to see how far they are relying upon these charts and I was a bit perturbed to find the coat of the head of a department covering the charts. The reception given to charts disappointed me. I presented myself in his office the next day to talk to him about the charts. When he came, he scrutinised the charts and told me that the chart showed high breakage rate and that he was going to the shed to investigate. I was happy to note the double purpose served by the chart.

In the processes where machine adjustments are done (e.g. pinion change in drawing, setting gauges in winding and adjusting the belt of scutcher in blow room) the control charts are found to be very useful in deciding whether an adjustment is necessary.

(c) Establishment of the Quality Control Department on a Permanent Basis :

The statistician takes some time to understand the working conditions and organisation of a mill where he is to work. Also any new department or any new technique to assist the technicians is treated with suspicion and as unwanted interference. The statistician and his staff therefore need an assurance that they will be retained for some years so that they can start to work gradually and meanwhile establish contacts with the technicians on a friendly basis.

Experimentation

Statistically designed experiments are conducted to assess the working in subsequent stages of the process whenever a change is envisaged at a particular stage. Such experiments are so designed that the effects of chance causes and spurious variations not pertinent to the comparison do not affect the conclusions drawn. The difficulties in conducting properly designed experiments are not few, especially when the process is hand to mouth.

Considering for example the experiment we conducted to study a new method of preparing the ribbon laps, the storing of the material at each stage, the interchanges done etc. upset the normal production to a great extent. Naturally the technicians were puzzled because they have to maintain a level of production ; piece workers too started complaining. We could not conduct the experiment in a simpler way either. In such circumstances it is for the management to take suitable action to allay the fears of the workers and technicians.

Another experiment was conducted to find the difference in working (as reflected by breaks) between two types of healds. During the experiment healds had to be interchanged with a view to eliminate loom and operative differences. Our attempt to get it done was a failure and the experiment had to be given up, though the technicians told me that they were satisfied with the results already obtained.

The training of technicians and management in quality control techniques, started by ATIRA, will go a long way to ensure the support of management when process is upset as regards production, wages, etc.

The following are some experiments which have to be conducted over a long period and which we may term as project.

Work has been started to evolve a sampling scheme to accept or reject store accessories like bobbins, shuttles etc., supplied by the merchants. The importance of supplying standard materials to departments need hardly be stressed. Since no work has been done earlier, the preliminary studies are bound to be very expensive and time consuming. It was decided to test bobbins under the mill conditions. It took us three months to convince that sound sampling scheme will be very effective in controlling the quality of incoming articles.

In another instance it was desired to know the life of picking bands. As the life of picking bands is more than a month it took us two months to complete the investigation. Such investigations take a long time and can be carried out only with the co-operation of the management, technicians and labour.

Reorganisation of Departmental Records

The importance of good records and sound inspection schemes to an organisation employed in mass production is evident. Improper maintenance of such records may mean higher costs and less reliable results. Many times we come across situations in the mills which involve duplication of work e.g., wrappings, damage inspection etc. Hence attention has to be paid to standardise procedures of testing and inspection required at the various stages of the process.

In all I have narrated so far, one could not have missed the fact that time is a very important factor in making the working of this section a very useful tool for making the process economical and efficient.

Future of Investigators

One word about the investigators who work in this section. Their future is rather uncertain ; their scope to rise up is not bright, since there is false notion that the investigator is not suitable for departmental work. On the contrary the investigator is fully conversant with statistical methods. It will be very useful for the work of the statistics section if the investigators are given scope to work in the department after some time.

I am very happy to say that in our mill investigators have been taken up as supervisors by the management. A suggestion in the end will not be out of place. Any apprentice technician who is employed in the mill must be asked by management to work at least for three months in this section which will enable him to get an intimate knowledge of "what is what" in the process and the same person later will give us the best cooperation either in maintaining control charts or in conducting experiments or projects or developing and organizing the departments for better testing and inspection.

I wish to express my thanks to the management of our mill who have kindly allowed me to read this paper.

ORGANISATION OF DEVELOPMENT DEPARTMENT IN TEXTILE MILLS WITH SPECIAL REFERENCE TO SQC UNIT

C. R. Asnani

Raja Bahadur Motilal Poona Mills, Poona

Organisation of SQC

In the organisation of a textile mill as a whole the statistical quality control unit could just form a section of a larger department which may be called a development department. While attempting to draw attention to the over-all picture of a development department, the main emphasis would still lie on the problems relating to the SQC unit, which has by now, formed the foundation of the development department in most of the mills. There are, however, a few instances in which the development department had its beginning from the top i.e. with the appointment of a development officer to make a start in other directions first and then add to it the SQC unit.

Whichever way the start has been made the ultimate objective should be the same, viz., to establish a development department of suitable size in every textile mill. In either case the organisational problems are almost identical, whether we start with the statistician as the head of statistical quality control unit or with a development officer as the head of development department. Hence what is said for one is equally applicable to the other.

Most of the mills which have made a beginning in this direction have the followng set up :

> One qualified statistician is in charge of the SQC unit with 3 or 4 investigators. The latter are usually technically qualified but the statistician acquires a knowledge of textile technology by experience in the mills and from the training provided by ATIRA under their servicing and supervision schemes.

Broadly speaking the SQC units working in different mills can be put into two categories :

(i) Those which continue to have servicing and supervision schemes,

and (ii) those which have become almost independent after getting servicing and supervision from ATIRA for two or three years.

The scheme of servicing and supervision is extremely useful in as much as it helps the programme of statistical quality control to get roots in the mills on one hand and on the other hand enables the statisticians in charge, who are generally fresh from universities, to develop the necessary skill to run the section smoothly, even after the scheme is withdrawn from the mill in due course.

However, inspite of the above preliminary training, there is always a possibility of a number of problems cropping up ***which appear to be inherent*** in the very system.

Some of the important ones are mentioned below and suggestions to avoid them are offered.

Suggestions for Successful Working of SQC Departments

In the initial stages the statisticians due to lack of experience are likely to exploit their key position in the organisation by directly dealing with the management, on departmental matters over the head of the technicians in charge of the department concerned. This attitude is more likely to create problems than solve. A more appropriate method would be, to always keep the head of department concerned informed about the data collected in his department and the inferences drawn therefrom. The management should encourage this system to grow as a matter of their *own* policy.

There is generally a lack of cooperation between the technicians and the statisticians, which greatly impedes implementation and retards progress. This is partly due to ignorance on the part of technicians about the statistical techniques, but mainly due to improper approach. To ensure adequate cooperation, it is essential to actively associate the heads of the respective departments, in the planning as well as implementation. The programme for the SQC unit should be planned on monthly or quarterly basis, and this should be done jointly by the heads of departments and the statistician, after due discussions in formal meetings, held periodically. However, such meetings between two persons, who have not yet developed a common way of approach or thinking, would rarely yield good results. Hence to make this procedure effective, it would be advisable to actively associate a technical manager or a production manager with such meetings. If however there is a development officer besides a statistician, he should come in the picture in normal course as a third member. In absence of any of them, being available in an organisation, active participation of ATIRA officers, at least in planning becomes all the more necessary. If such meetings are held in the presence of the managing agents, they are likely to yield better results provided the agents are able to resist the temptation of finding fault with the technicians.

Next comes the relationship between the statistician and the investigators, which offers yet another practical problem. To start with, the statistician has little knowledge of textiles and the investigator of statistical techniques. A sincere and enthusiastic cooperation between the two such sets of persons would need a very skilful handling on the part of the statistician. The acquisition of substantial knowledge of textile technology on the part of the statistician and a good working knowledge of common statistical techniques on the part of investigators should go a long way to cement the relationship between the two. Investigators need proper coaching in statistical techniques by the statisticians, who in turn should add to their knowledge of textiles by seeking help from the investigators as well as the technicians working in the mills. This would help the two to work as a complementary team and thus ensure the success of SQC unit to a great extent.

The investigators after successfully working for two or three years are likely to pose a question. "How long are we going to serve as investigators ?" There will be hardly any chance for them to work as statisticians — the next higher post. The answer to this question would be to *encourage* them to get into the production departments where, with the background of statistical techniques, they would prove more useful supervisors than otherwise. Acting in a different way would mean losing both a good supervisor and a good investigator which the organisation can hardly afford to. The management would therefore do well to announce their policy in this regard and set at rest the doubts of technical investigators.

The ultimate object of SQC unit should be to make the new techniques acceptable to and popular in the industry by

(i) making the technicians statistically minded and encouraging them to use such techniques by themselves and

(ii) helping them to design simple experiments on correct lines and coaching them in drawing correct inferences from the results.

To achieve this objective, it may be worth while starting training classes for assistants and supervisors and the mill statisticians should be well equipped by ATIRA to conduct such classes in their respective mills. The present arrangement of training technicians by ATIRA would just touch the fringe of the problem.

Development Department

SQC units started in mills outside Ahmedabad will have to face greater difficulties initially, as day to day advice and help offered by ATIRA officers to the units under their servicing and supervision schemes would not be available to them. However this difficulty would be greatly obviated if such mills have got some sort of development department already established.

A full-fledged development department should roughly consist of the following sections :

Production
Waste
Stores Consumption
Time and Motion Study
Physical Testing Laboratory
Chemical Testing Laboratory
Training Within Industry
and Statistical Quality Control.

A development officer may be either a textile technician or a statistician or a TWI trainer or a chemist. He can hold one of the sections as a direct charge. The mills situated at Ahmedabad which can get prompt service from ATIRA, however, may not find it essential to set up physical and chemical testing laboratories for some time to come but for the outstation mills they are an urgent necessity. In short, the textile mills need some sort of miniature " ATIRA " in their own premises.

ORGANISATIONAL ASPECTS OF SQC WORK IN MILLS

S. N. Bhaduri
Liaison Officer, ATIRA, Ahmedabad

I shall try in this paper to explain the scope, structure and functions of the quality control sections in mills and to point out certain difficulties from the organsiational point of view. I also hope to be able to start off some discussion on important organisational problems.

Statistical quality control units were first established in Ahmedabad under the sponsorship of ATIRA in three local mills in the beginning of 1950 as an experimental measure. The work done by these teams was found to be of such practical benefit to the mills that ATIRA was able to convince a large number of mills to set up similar sections. At present in Ahmedabad alone there are 27 mills which are having their own quality control departments. A large number of mills are desirous of starting this work. A more rapid progress of the implementation of statistical quality control is only restricted by the non-availability of suitable staff and the limited personnel at ATIRA'S disposal.

How We Set up SQC Sections in Mills

It will probably be of interest if I describe how we go about setting up the quality control section in a mill. The first step is, of course, to get the mill management and technicians interested in the work. This is done through personal meetings with the management and the staff both at the mills and in ATIRA. In such meetings the work done by the quality control sections is explained in detail with the help of actual reports, charts and figures. Sometimes it is necessary to conduct surveys in the mills which are aimed at demonstrating to the mills the utility of having a regular system of collection of data. The salient points arising out of the survey are explained to the management and the staff showing how collection of data along statistical lines helps in taking proper corrective action. The need for conducting statistically designed experiments is explained and sometimes demonstrated. The staff and the management are encouraged to attend the quality control classes sponsored by ATIRA so that they can realise, with the help of actual data collected from mills, the scope of statistical methods. Once the management and the heads of divisions are convinced about the benefits to be derived from the establishment of such a section, ATIRA proceeds to select the personnel and make arrangements for the necessary training. One very important point I would like to emphasize here. It is of the utmost importance to win the support of the technical staff from the beginning for the establishment of this section. We have met with failures in the past because in some cases the sections were established at the request of the management without any attempts to convince the technicians. The natural result is a suspicion on the part of the heads of the departments. This is bound to doom the quality control section from the start. We cannot, of course, refuse to help the management of a mill in starting such a section but we try our best to explain fully the scope of such a section to the technicians to get their support. I am specially bringing the attention of the managing agents present here to this very vital need of consulting their departmental heads before requesting ATIRA finally to start quality control.

The present structure of the quality control section in mills is the following. The head of the section is a qualified statistician. To help him there are usually three or more technical assistants or investigators. In passing I may mention that ATIRA has been facing considerable difficulty in the selection of suitable statisticians. While there are plenty of statisticians very few have got the aptitude or the inclination to work in the industrial field. In the selection of investigators our practice so far has been to appoint these assistants from people who have just passed out of the technical institutes and who have therefore a fresh and completely objective attitude to the quality control work. As a general rule we think it is inadvisable to appoint the technical assistants from amongst the supervisory staff already in the mill.

The quality control section is a separate department in a mill responsible directly to the management like any other department but working in close cooperation with the departments. When a statistician is first appointed in a mill he is usually innocent of any technical knowledge in textiles. He requires a minimum period of six months to a year before he is well versed enough in textile technology to carry on the work on his own. During this period he works in close collaboration with and is trained by an experienced ATIRA staff officer who visits the mill for at least 3 half days a week. After, at the most, a year this service from ATIRA is withdrawn and the statistician is left on his own resources mostly. However, ATIRA continues for a nominal fee to send an officer at least once a week to the mill. This officer helps the statistician who is still comparatively inexperienced in planning his work. The aim of ATIRA is to make the mills self sufficient as far as the quality control work is concerned. With statisticians who do not receive any regular visits from ATIRA contact is still maintaned through monthly meetings of statisticians and occasional consultations. The establishment of quality control sections in mills can proceed in two ways. One way is to appoint a statistician and train him in textiles. The other is to appoint or transfer a technologist to this post and give him the required training in certain basic statistical techniques. Both systems have got their advantages. We have adopted the first system but are not averse to the second. In fact in one of our outstation member mills we are experimenting with the second method. I am not elaborating on this point further at this stage since I expect it to feature as the subject of much lively discussion.

Scope of SQC sections

The scope of quality control sections in the mill is much wider than the term SQC would signify. In fact the keeping of control charts is only a very small part of the work of the section. The work of the SQC section is mainly three fold.

(a) To collect, tabulate and analyse systematic data on important operational characteristics. This includes the use of various statistical techniques such as analysis of variance, regresssion analysis, control charts and acceptance sampling. In many instances mere collection and tabulation of data is of sufficient value to justify the existence of the section. This is the most important function of the section.

(b) To conduct statistically designed experiments to test between several treatments and to interpret the results to the management and the technicians.

(c) To act as a general liaison between ATIRA and the mills for communicating information and helping to implement various ATIRA projects in all sections. This last function is of ever increasing importance. The original concept of the SQC sections as being responsible for functions (a) and (b) only has had to be modified in the context of the needs of the industry. The SQC sections are now visualised as the nuclei of bigger development sections which are essential in every mill for implementing new ideas and for systematic testing and experimental work. The statisticians already working in the mill are at vantage points of established position and can look forward to an increasing sphere of activity and responsibility.

How to Make SQC a Success

The function of the SQC section is to point out with the help of systematic data where action should be taken to reduce variation in regard to different characteristics or to reduce waste, breakages, etc. An intelligent and alert statistician will also be in a position sometimes to suggest methods for effecting such improvements. As a result of the experiments he carries out he may be able to make definite suggestions as to which of several treatments to adopt and to assess in practical terms the advantages of adopting such a treatment. It is not within his power actually to take the technical actions which will result in such improvements. This must be clearly understood.

Very often it is forgotten by the management and technicians that the SQC section acts only as the eyes and ears of the departments and does not enjoy the executive functions of the hands. The practical benefits to be gained from the work of the SQC section will therefore depend entirely on the interest and the promptness with which its observations are acted upon. It is therefore of the utmost importance to evolve a working pattern within the mill which will ensure the maximum collaboration between the statistician on the one hand and the management and technicians on the other. The evolution of such a pattern is a painfully slow one at times and requires great tact and perseverance on the part of the statistician. The statistician should never commit the mistakes of divorcing himself from the departmental heads and appearing to the latter as a tool of the management only. He has to be in constant consultation both with the departmental heads and the management and has to draw up his programmes with prior consultation with both. He has to keep both informed as regularly as posssible of his work and review his work jointly with management and heads of departments every month. Only under these conditions can the statistician hope to see his work being rewarded in terms of actual improvements and technical actions and only this can ultimately prevent frustration. He has also to be particularly careful in keeping the interest of his technical assistants alive. Very often their work may become a routine or a drudgery to them or they may not fully appreciate the ultimate worth of their work. It is very important that the significance of their work be fully explained to them before assigning them their work. They should be made to feel that they are the most important units in the quality control set up. They should therefore be made to have a proper perspective of their work in relation to the quality control programme. All investigators if possible should be given an assurance that they will be absorbed in the production departments as soon as possible after serving in the SQC section for about one or two years.

I have already indicated the conditions under which SQC can become a success. I will elaborate these a little further now and mention the actual difficulties in the way. When a statistician first comes to a mill he usually feels like a fish out of water. It takes about a year for him to gain sufficient knowledge of the technical processes involved and "to know the ropes". It requires constant study on his part to keep abreast of latest advances in technology. This is specially necessary since if he wishes to be listened to with respect by the technicians he should understand their language and be able to talk back in the same language. He has gradually to convince the technicians as well as the management of the useful role he can play in the mill economy and win their confidence. All this takes time. The first requirement therefore is a reasonable assurance of his stability in the mill so that he can put forward his best. Many statisticians have left in the past because they did not feel secure in their posts. I am not saying their feelings were justified — I am inclined to think that in most cases they were not. But the very indication that such feelings exist is disturbing. Probably these are created when the statisticians witness the rapidity with which the managing agents keep on changing their heads of departments. It is also true that after working in the mills for one or two years the statistician may receive tempting offers of salary which the mill is not willing to pay. This is a great practical difficulty. The second requirement is a proper understanding and cooperative attitude on the part of the management. There are two types of managements which are dangerous for SQC. The first is the indifferent type who will hardly ever meet his statistician. The latter would naturally feel neglected and in the long run frustrated. The second is the over—enthusiastic type who will insist on taking corrective actions everyday on the basis of the data collected on the same day, one of the corrective actions being an indiscriminate criticism of the departmental heads. For the success of SQC managements have to understand the limitations and the scope of SQC. If corrective actions are shown to be required, they should provide the necessary facilities to the departmental heads. The statistician must be provided with adequate staff and his programme should not be disturbed by day to day ad-hoc assignments once it has been fixed at the joint monthly meeting of the statistician and the heads of departments. Above all the management has to see to it that a healthy atmosphere is created for SQC work whereby the statistician is not used as a handle to brow-beat the heads of departments. The third requirement is the whole-hearted cooperation of the technicians. This is always forthcoming in ample measure once their confidence is won and the technicians come to regard the statistician as one of their own — working together in a common effort to improve the working of the mill. Occasional difficulties in the working of the SQC arise because some technicians take the results of observations collected by the statisticians as a personal reflection on their work or capability. This is a very awkward situation for everybody concerned and the only remedy lies in convincing the technicians that such observations are taken with no intention of discrediting them. It would be clear from all these requirements that the basic prerequisities for the success of the SQC section as far as the statistician is concerned are the qualities of adaptability, tact and perseverance coupled of course with necessary statistical and technical skill. He need not be a very sound theoretical statistician. Such theoretical problems as cannot be tackled by him can be referred to the statistics division of ATIRA which has already solved a number of vexing problems. Another important point is that the statistician has to be given a status and a position in the mill equivalent to at least an assistant departmental head so that he will be listened to with respect.

Managements and technicians would be in a better position to appreciate the work of the SQC section if they are given some basic training in the simpler statistical techniques. For this purpose ATIRA has been arranging periodical twenty hour courses in the application of control charts and the simpler techniques of statistical methodology. Whether such training classes are serving the needs they are meant to fulfill or whether they require to be modified into more intensive courses is a matter on which I expect constructive suggestions from this gathering. Mr. Asnani has proposed that such formal classes should be conducted by the statistician in his mill. I am inclined to think — this is my personal view — that a continuous and informal process of education and indoctrination of the managerial and technical staff, in statistical ways of thinking and methodology would be more effective. It would be very useful if basic statistical courses are included in the syllabi of the various technical institutes from which the technical personnel of the mills are recruited. With the object of encouraging and helping the technicians in simple applications of statistical techniques, the Quality Control Group has been formed which has done very creditable work. The enthusiasm of the technicians has to be channelised more systematically than has been found possible hitherto. One great handicap is the lack of facilities at the technicians' disposal for collecting data or carrying out investigations on their own — busy as they are with their day to day problems.

Dissemination of Information

Finally I will touch upon the need for a continuous exchange of information between the statisticians working in the industry. This is sought to be maintained through monthly meetings. The Quality Control Bulletin publishes the work done by the statisticians in mills as well as by ATIRA quality control teams. We are now not publishing a description of the routine quality control work in mills such as control chart applications, of analysis of variance for locating machine differences etc. since these are of individual mill interest. Only experimental work or investigations of a general nature, or new applications of statistical techniques are published. We would like to have the views of this gathering on the most desirable form of the bulletin. There are two factors standing in the way of more informative and instructive Quality Control Bulletins. The first is the growing secretiveness on the part of the mill managements and an inclination to disallow the publishing of any results obtained in their mills. The second is the ATIRA policy of not divulging the name of individual mills where work is done, with the result that individual statisticians whose names cannot be published feel that they are not given due credit for work done by them. This of course is not the intention of ATIRA.

DISCUSSION

Shri Navnitlal S. Sodhan (Agent, Sarangpur Cotton Manufacturing Co.) : The main difficulty with the management has been regarding the follow up of quality control work. Once the technicians have learnt the techniques how is the consciousness to be maintained ? I feel that the technicians are non-co-operative because they are not convinced of the advantages of SQC. Besides they have to get work from labour on the one hand and keep a check on quality on the other. Unless they are constantly conscious of quality, they would find co-operation with the SQC section difficult.

ATIRA was started for sharing the benefits of each others knowledge and therefore the results of the experiments conducted in various mills should not be kept secret but made open to all, without disclosing the identity of the mills where the experiments are conducted.

If there is a lack of trained statisticians, the idea of sharing the services of a statistician by a group of mills could be tried as is done by our group.

Shri S. N. Bhaduri (ATIRA) : At this stage I would like to clarify one point. We in ATIRA have never complained of the non-co-operation of the technicians. On the contrary, most of our work is the result of active interest taken by the technicians in ATIRA's work. Management also has been most cooperative but in some instances it has not taken a proper attitude towards SQC work and has made use of the work of these sections to criticize the technicians.

Shri E. R. Subbaram (Superintendent, Shri Ambica Mills) : If the statistician is given the status of a departmental head, as has been suggested, I am afraid complications will arise. SQC, TWI are all scientific methods of management and must operate in an integrated manner.

The investigators in the SQC sections do not have any future in the SQC section itself but would be of great use if absorbed in the production departments. A person who takes employment after technical training, generally, has an aversion to learning new techniques. SQC should therefore be taught in the technical institutions themselves.

Shri Kanchan C. Parikh (Agent, The Ahmedabad Jupiter Mills) : With a meagre staff of three investigators SQC cannot be introduced in all sections of the mill even though SQC work is desirable at all stages. Further, it is very difficult to keep a regular day to day check even in only two sections, spinning and weaving. We, in our mill therefore have introduced a system of making a thorough check in a randomly selected week in all sections of spinning and weaving. This gives an indiation of the quality of product from time to time. This has to be done, because keeping a check on one section and neglecting other sections during that period is not advisable.

Shri B. Sarkar (Statistician, The Ahmedabad Manufacturing & Calico Printing Co.) : It is very essential to apprise the management and technicians of the role of SQC work.

The statistician with a limited knowledge of textile technology has direct access to the top management and it is therefore likely that the cooperation of the technicians to SQC work is lost. It takes some time for a statistician without skill in dealing with technical problems to decide his code of behaviour with others. I faced these difficulties in the beginning but now I get the best cooperation from the technicians and am one among the departmental people with whom I am working. The staff of my section has steadily increased as the management felt the need of controlling quality at more and more stages. Now I have separate staffs for routine work and experimentation. The routine checks enable to trace the causes of variation before they create any trouble. The technicians locate the trouble and take action because my section does not go to the management on such matters.

Shri B. B. Mitra (Spinning Master, The Aruna Mills) : I feel that there is a lack of scientific attitude among statisticians. They just read some textile journals get new ideas and try to implement them indiscriminately. For example, too much has been made in the past of the benefits to be expected from a control of full lap weight but to my knowledge these claims had not been substantiated by any experiments.

The statistician must interpret his data on a technological background. When there exists a variation in raw materials the extent and effects of which have not been studied it is dangerous to jump to conclusions because a difference which a statistical technique may show to be real may not at all be important technically.

No management can get any benefit either from SQC work or from the technicians if the attitude of the management in starting an SQC section is to keep a check on the departmental heads.

Technicians should have a knowledge of the basic principles of SQC and for this purpose training in SQC should be imparted in technological institutions as is the practice in Manchester.

Shri S. N. Bhaduri (ATIRA) : The indiscriminate emphasis on blow room control in the initial stages was due to our lack of experience. I cannot see Shri Mitra's point that the statisticians lack scientific attitude because the very concept of SQC is a scientific approach. Our suggestions on "Soft Waste Mixing" and "Improved Method of Ribbon Lap Preparation" are based only on the results of a number of experiments conducted in various mills.

SQC sections are conscious of the need for testing raw materials but for this, every mill must be prepared to set up a small testing laboratory. In the absence of such a laboratory we have adopted the Small Sample Spinning test for finding the spinning value whenever possible.

Shri V. D. Pendse (Statistician, The Rohit Mills) : A solution to the problem of having a sufficient staff in SQC sections is to incorporate all the testing and inspection sections into a single SQC section. This would avoid duplication of testing and inspection also and the technicians and management would get the necessary information collected in a systematic and scientific manner. The statistician would do well to devote his energies towards organising the testing and inspection departments in the initial stages before proceeding to other work. For this period he should be trained in ATIRA.

SQC and other techniques of scientific management should not be introduced as a fashion but only when the whole organisation has reached a certain standard at which these techniques will be received, absorbed and implemented.

Shri S. J. Bose * (Manager, The Rajnagar Mills) : Even if the testing work is carried out by the SQC sections the technicalstaff should collaborate with the SQC section and make use of the data collected. For small mills, additional technical staff for routine collection of data will serve the purpose. In the long run the expenditure on the additional staff is bound to prove fruitful. I may mention here that in a mill in Orissa all the testing and inspection is carried by a separate department.

Shri N. Subramaniam (ATIRA) : A testing section must be independent of the production departments for objective collection of data and that is why a statistician should have an independent status in a mill.

Dr. Walter A. Shewhart : It does not matter whether a technician trained in statistical methods or a statistician trained in technology is in charge of SQC work. What is important is the interest created in SQC work among the entire mill staff. The large gathering here for discussing the organisational problems indicates the excellent work you have done in the last five years. I do not know a single instance where SQC techniques applied in the right method have not been of economic utility.

Shri S. M. Jaya Rao and Shri D. R.Sharma (ATIRA) also participated in the discussion.

Dr. Sarabhai (in his concluding remarks) : I am sure this discussion will be very helpful to us for future development since it is only after hearing both sides that we can come to proper decisions. I suggest that the proceedings of this session be circulated to all technicians and management.

At a later session Dr. Shewhart raised some points which initiated a lively discussion. We have thought it relevant to report the discussion here for the sake of continuity.

Dr. Shewhart : The papers read in these symposia show the progress you have made in developing statistical methodology. But what is more important from the view point of better quality is the quality consciousness aroused in the operatives. I would like to know what efforts have been made in this connection.

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* Now General Manager, The Orissa Textile Mills Ltd.

Dr. Vaswani (Head of SQC Unit of Indian Statistical Institute, Bombay) : In Bombay SQC techniques are being made popular amongst technicians by courses but I would like to know from Dr. Shewhart as to what can be done when the workers are illiterate.

Dr. Shewhart : Even if the workers are illiterate they should be trained in correct methods of doing their jobs. Secondly the SQC section should find out the specifications for defects which can be tolerated and lastly keep charts on each and every machine in such a manner that the operative can undestand his performance.

Shri Bhaduri (ATIRA) : ATIRA has been doing this work in collaboration with its T.W.I. section. Even though no formal training in SQC is given to workers, an attempt is made to get cooperation by explaining to them the importance of maintaining quality in the material. For example, the group norm charts for controlling damage are fully explained to the worker. However in the majority of cases it is the supervisor and not the worker who is responsible for taking action on the basis of control charts and it is therefore necessary as a first step to train the supervisor in the techniques of quality control. This, ATIRA has been trying to do by organising classes for them periodically. These courses may not in their present form fully meet the need of the supervisors and that is why ATIRA is reorganising these courses in the near future. I thank Dr. Shewhart for his very useful suggestions.

Dr. V. N. Patankar, Shri N. Subramaniam and Shri S. M. Jaya Rao also participated in the discussion.

SESSION II *

" Case Histories of Quality Control Work in Industry "

[Held in ATIRA Auditorium on Friday, 31st December, 1954. Shri Champaklal Nathalal, President, Quality Control Group ; Agent, The New National Mills Ltd., Ahmedabad, in Chair]

INTRODUCTORY REMARKS BY SHRI CHAMPAKLAL NATHALAL

I have great pleasure in extending, on behalf of the Quality Control Group, a hearty welcome to our distinguished guest Dr. Walter A. Shewhart. We had often in the past heard of Dr. Shewhart's name being mentioned as the father of statistical quality control techniques. We are indeed very fortunate today in having been honoured by his presence. We thank you, Dr. Shewhart, for coming and attending the Symposium which is to start just now.

Before I call upon the first speaker at today's symposium, I would like to say a few words about our Group. This Group was formed over a year and a half ago, immediately after the first course of lectures on quality control meant for representatives of management and technicians were delivered. The Group has since then grown in strength with additions to its ranks after each subsequent series of lectures. The membership is about a hundred now. The Group is open to all technicians and management people who have taken a course of lectures in statistics. Others interested may become Associate members. After attending courses of lectures on SQC the members of the Group have made a few applications on their own initiative and with the help of the statisticians in the mills. We have an interesting record of work which has from time to time been published in our Newsletters. In the symposium this evening a few papers connected with actual case histories of applications will be read.

I might also add a few words about continued application of control chart techniques in textile industry. Despite the limitations in their utility due to causes which are inherent in the nature of the raw material and the manufacturing processes, they are of very great value in textile manufacture and deserve all efforts at starting and maintaining them. The group has done particularly useful work in popularising the use of simple designs of experiments for comparison of various treatments. The main achievement of the Group has been in creating a consciousness of the need for objective collection of data and a scientific interpretation of the same. I hope today's symposium will go a long way in increasing the enthusiasm for application of control charts and other statistical techniques in our industry.

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* This session was organised jointly by ATIRA and the Quality Control Group, Ahmedabad.

SQC — WHAT IT HAS DONE FOR ME

D. A. Gidwani

Spinning Master, The Aryodaya Spg. & Wvg. Mills Ltd., Ahmedabad

SQC—A Pointer for Action

One of the greatest and commonest problems confronting any one working in the textile industry is that of variability, which occurs at all stages of manufacture, from raw material to the finished fabric. In order to have the best possible results it is necessary to exercise utmost care at each stage of manufacture and in statistical quality control, a technician finds a handy and effective tool to keep check on variation.

Even before the advent of SQC, there were rule-of-thumb methods by which variation was sought to be controlled ; for example, in blow room an arbitrary limit was fixed and laps were accepted or rejected depending on whether their weights fell within or beyond the limits specified. Similarly in drawing and ring spinning departments the average weight of material was kept within desired limits by means of pinion changes. But these methods did not help materially in giving an idea of the inherent variation of the product and the limits often were not in accordance with the natural limits of variation. Moreover such data did not show when an adjustment was necessary and often it has been the experience that after making a change, it became necessary to revert back almost immediately suggesting that the change made was not quite warranted.

Statistical methods in general and quality control techniques in particular are quite helpful to a technician in the following ways :

(i) to estimate the true average and maintain the average within prescribed limits ;

(ii) to locate the assignable causes of variation leading to corrective action ;

(iii) to control variation at each stage ;

(iv) to assess the effects of any major changes made in the process ;

and (v) to decide on optimum settings, speed etc.

I will mention a few instances where the techniques were helpful to me in making improvements in my department.

C—Charts Help Reduce End Breaks

(i) We are maintaining C-charts on end breaks in ring spinning, in 70s warp. During one period the chart revealed a significant increase in breaks and an investigation disclosed it to be due to spewing. Consequently, twist was reduced in roving and breakage rate came down to normal. Thus it was possible to rectify the defect before it upset the working of the department.

Normally, any such increase will not be detected till it is brought to the notice of the authorities by the workers in the form of a complaint. And this does not happen generally, unless the increase is there for a reasonably long period, say 4 to 5 days for the worker to notice it. Then it will take still further time to verify whether the complaint is genuine, before proceeding to investigate into the causes, whereas with a control chart one could clearly see when a change has occured and when action is needed.

(ii) In 90s weft our breaks, we felt, were somewhat high. So in order to reduce the rate, we made the roving finer, thereby reducing draft in ring spinning. The breakage rate immediately came down and the difference was clearly shown by the chart. Further it was noticed that all the points that went out of control were from three particular frames. This led to an examination of these frames and it was found that they had low quality rings and higher speeds compared to others.

(iii) We spin 44s warp from two different mixings, Egyptian and African. From C-charts kept for end breaks in ring spinning, we found, strange as it may seem, African variety always giving significantly less end breaks, though both were worked in the same type and make of frame. The two groups of frames working on African and Egyptian were compared and the only difference was found to be in roller settings, the Egyptian variety having wider gauges as compared to African. An experiment, designed statistically, was conducted in frames working on Egyptian to compare the existing settings with those kept in African. The narrower settings (used in African variety) gave significantly less end breaks, other factors like lea strength, evenness etc., remaining more or less the same. These settings were kept on frames workng on Egyptian and the breakage rate came down substantially.

(iv) A study conducted in our mill and elsewhere has proved that the presence of excessive soft waste lowers the quality considerably, resulting in reduced yarn strength, higher breakage rate and more neps. With a view to keeping a control on soft waste, a thorough investigation was carried out and standards were specified for maximum soft waste allowable in each section. I will just mention how we arrived at the standards in one section viz., carding. In this department, soft waste occurs mainly at the time of stripping. From card-wise data collected for a sufficiently long period an estimate was made as to how much should occur per card per stripping. With that as the basis and giving certain allowances for other types of waste such as those occuring at the time of lap change, singles, doubles etc., (all based on observations collected for a sufficiently long period), it was possible to arrive at a standard much lower than what we were getting. Such standards fixed for each section helped in maintaining our soft waste at a reasonably low level.

I have attempted to outline only a few of the problems which the technicians will be facing in their day to day work. Statistical techniques provide points for timely action. But they require systematic maintenance of control charts and periodical experimentation. These may well be beyond the scope of the normal work-routine of a technician, calling for the services of a special staff for this purpose — staff for maintaining the charts and to conduct necessary experiments and interpret the results thereof to the technician. It will definitely be money well spent to have such a source of action to rely upon.

QUALITY CONTROL FROM A TECHNICIAN'S VIEW POINT

H. C. Parikh

Weaving Master, The Vikram Mills Ltd., Ahmedabad

In my opinion, quality control is in existence ever since the inception of this universe. Quality control is in practice in all walks of life.

We have gathered here together to talk of quality control in our factories, where we are passing the major portion of our time. From my humble opinion it is the proud privilege of the top, when the question arises as to who should begin and whose proud privilege it is to begin.

I am at this time reminded of my boss, the late Mr. Ben Marsden, Agent, The Marsden Mills Co. Ltd., who always used to tell us that slackness always comes from the top. According to his theory, he always used to supply the best stores and cotton. Even in those days i.e. 30 years back, he was always very particular for quality, both of yarn and cloth. He was, at the same time, very particular about humidity also. If the above mentioned facilities are given, I am sure that no technician will lag behind. He will certainly do his best and give the best quality and efficiency also.

The following are some of the sources which influence the quality of the product.

(i) Humidity
(ii) Supply of store accessories
(iii) Co-operation among all officers and assistants concerned
(iv) Trained labour guided by a sound labour organisation like the T.L.A. of Ahmedabad.

The poor quality of its finished product in a competitive market is bound to drive a mill to an unhappy existence. Whenever the quality of finished product is poor, it is always traced to these factors mentioned. Hence the need for a systematic collection of data and interpretation on a sound basis either in the form of ordinary charts or quality control charts will be very essential to assess the degree of influence of each factor in maintaining the quality of the product at the desired level. With factors, like below standard shuttles or bobbins etc., or absence of good understanding between the technicians and labour influencing the process, the question arises as to how quality control can work efficiently in day to day routine work.

In the warping and sizing sections, charts maintained on production and breaks (lappets in sizing), every day, will be beneficial because almost all the workers come from middle class educated families and are literate. This is not the case in the winding section.

By making use of quality control chart techniques and quality control methods, I personally feel that there is still a lot of room for improvement in quality and quantity. In my opinion because of the labour laws at present in force in our country, the co-operation between the labour and technicians is not as it ought to be. Hence the question is how to arouse the same feeling as I have got, as regards to quality control charts and quality mindedness among workers.

Under the guidance of ATIRA, quality control sections have been opened in the mills. As the technicians engaged in this section are many times fresh from institutes or colleges, they do not understand the practical aspects. So in my opinion the technicians engaged in the quality control sections should be put under the direct control of the heads of the departments so that they may be guided in the right way to fill up the gap of theory and practice, which will avoid friction between management and quality control section on one side and heads of the department on the other side.

GROUP CONTROL CHARTS IN TEXTILE INDUSTRY

V. Sreenivasan

Statistician, The Vijaya Mills Ltd., Ahmedabad

Introduction

The group control chart has the advantage of compactly presenting, in a single chart, the information on a number of machines working on the same specifications, thereby facilitating interpretation and saving the labour involved in maintaining individual charts. The necessity for and the circumstances favouring the application of such charts in textiles are not wanting. My aim in presenting this paper is to relate the difficulties I have encountered in making use of these charts and to point out certain modifications which may increase their utility. Three typical examples have been chosen for the purpose of illustration.

Group Control Chart for Wrappings in Ring Spinning

An ordinary control chart was kept in the ring spinning department for the lea-weight (which has been found to follow the Normal Law) of a number of frames working on the same count (62s warp), having first established the possibility of treating the different frames as different rational sub-groups by testing and verifying that there can be no significant difference between the frames. This was continued and whenever points went out of control, suitable actions were taken as far as possible and all the frames were brought under control after a certain period. When this state of control continued for some time, it was found to be laborious to go on plotting everytime all the points, and to find all of them under control most of the times. It was therefore decided to take advantage of the group control technique.

Every time four bobbins are collected from each of the seven ring frames (Nos. 34 to 40) spinning 62s warp and lea wrappings are taken, one from each bobbin, and the averages ($\overline{X}$) and ranges (R) for the different frames are calculated. The maximum and minimum of the $\overline{X}$'s and the maximum of R's are plotted along with the frame numbers on the $\overline{X}$ and R charts respectively. The central line on the $\overline{X}$ chart is drawn at the value $\overline{\overline{X}} = 16.13$ grains ; corresponding limits are determined on the basis of the value of average range $R = 0.70$ grains at which the ordinary control chart stabilised prior to starting the group control charts. Chart I is an illustration of this.

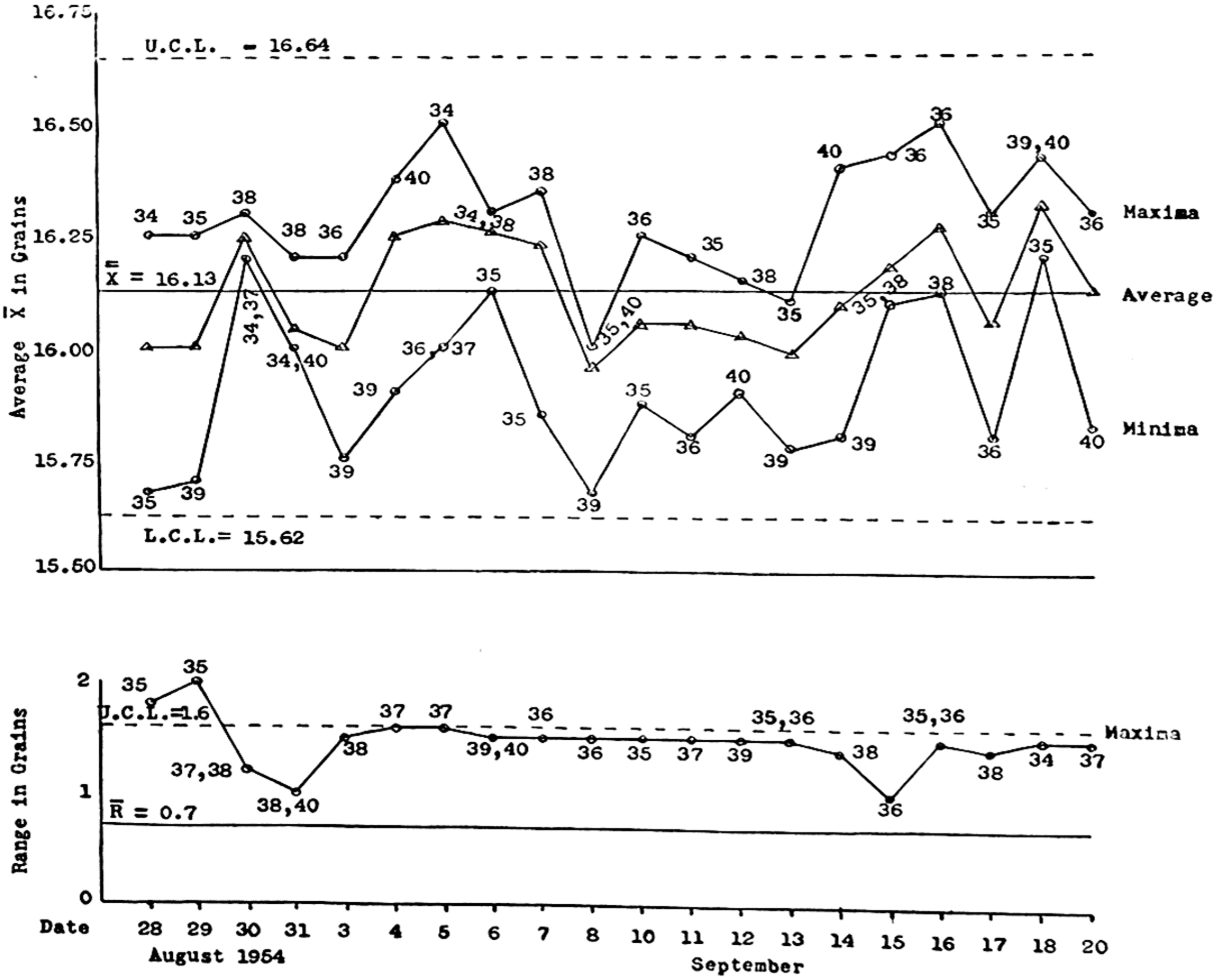
When the extremes are under control, no action will be taken but if anyone of the points goes out of control, all the frames above the control limits will be examined for any necessary action. Also when the same number repeats itself oftener than others on the chart, that frame may be selected for detailed investigation. Whenever actions are taken on the back processes with a view to reduce the ultimate variations in the yarn, the charts are studied critically to see whether it is necessary to narrow the limits.

Thus we exercise control on the variations. But at the same time it is necessary to have some idea of the general average level itself of such an important characteristic like the lea-weight which determines the count of the yarn spun. For this purpose, as can be seen in chart I, the group average is also plotted along with the extremes. The exact idea is not to control the average level. But whenever a run of such points above or below the central line occurs, it will help the technician to decide, in conjunction with other factors like climatic conditions, relative humidity, changes, if any, in cotton mixings, stock position and beam count, whether it is necessary to effect a pinion change or not. At no time, it will be necessary to shift the central line, which is drawn at the standard value, since it is always the aim of the pinion changes to maintain this standard.

CHART I

Process : Ring Spinning
Nos. of frames : 34 — 40

Count : 62s warp
Sample Size : 4



Thus this sort of group control chart serves not merely as a guide to control the members of the group but also remains as a condensed progress record containing valuable and important information about the group.

This chart is applicable even if a few machines are not working at times, because the limits are still based on the within variations of all the members and again the sample size is always kept constant. But whenever a new machine is to be included in the group, it is necessary to satisfy that its level and variations are similar to the original members of the group.

A Modified Group Control Chart for Stoppages in Automatic Loomshed

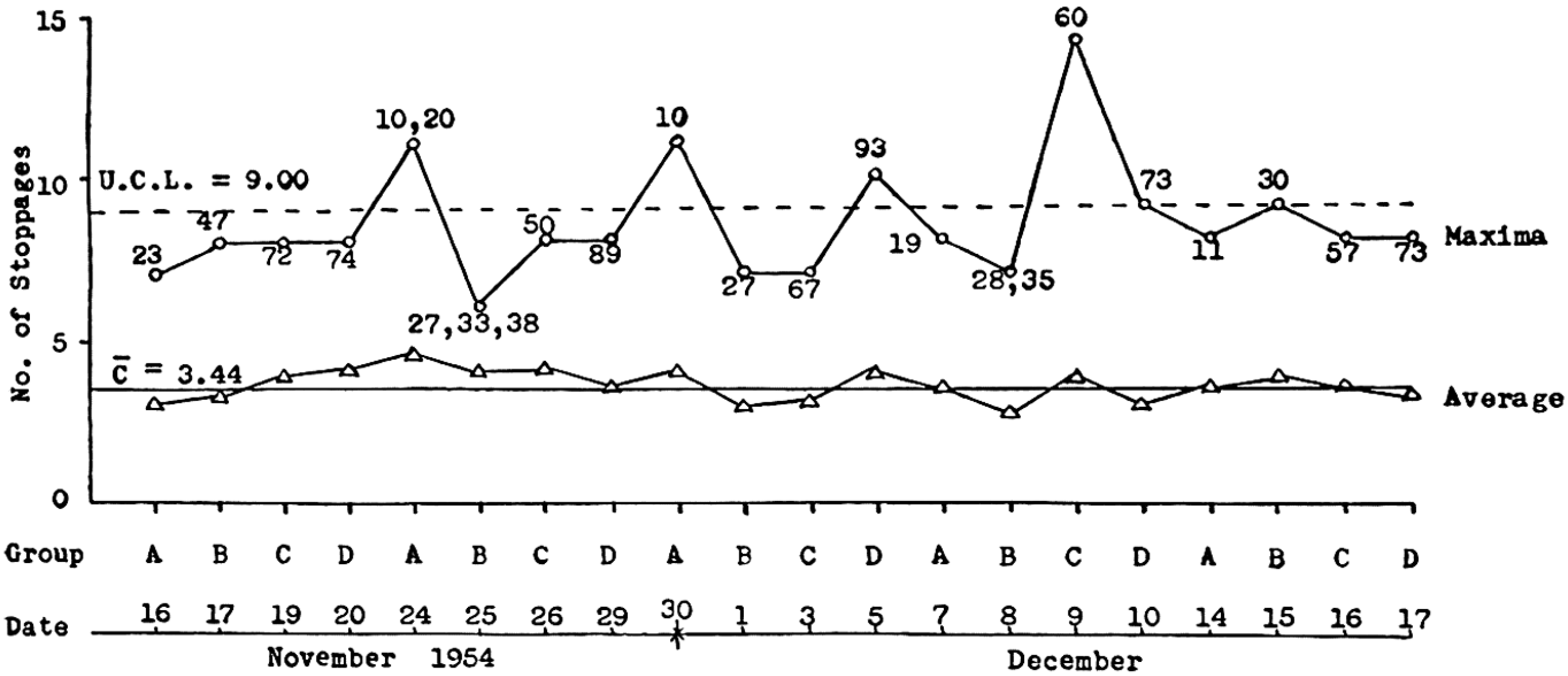
An attempt is also being made to study the applicability of the group control chart technique for a variable which follows the Poisson distribution. The variable chosen is the total stoppages per loom hour in the automatic loomshed which has been found to follow Poisson Law. The necessity for such a method is the same as in the first example. Here a group consists of 24 looms attended by a single weaver. There are four such groups in the whole shed. A trained investigator observes a set of 24 looms at the same time for stoppages during one hour. Daily only one group of 24 looms attended by one weaver is observed and the cycle is repeated every week. In view of the different days on which the observations are taken, the four weavers are treated as forming different groups. These groups are similar in the sense that the type and the year of make of the looms attended by them are all same. Also the same sort of cloth is being woven by all of them. The only difference is that they are not all observed on the same day. But anyhow a method of treating a set of similar groups in the same chart is conceivable in view of the conditions expressed above. It is also strengthened by the fact that it has been tested and found out that there is no significant difference between the four groups in respect of the total stoppages.

In Chart II, the maximum number of stoppages for each day is plotted together with the loom number.

CHART II

Process : Automatic Loomshed
Count : 18s/24s
Characteristic : Total stoppages per loom hour

Group	Looms
A	1 – 24
B	25 – 48
C	49 – 72
D	73 – 96



The limits are found out as for any C-chart, the central line is at $\bar{c}$ and the limits at $\bar{c} \pm 3\sqrt{c}$ where the average c has been determined by taking into account all the machines.

As shown in Chart II, the group average is also plotted everytime. Whenever the averages of all the four groups are on the same side of the central line, it can be tested to find out whether the average number of stoppages for the shed as a whole has altered.

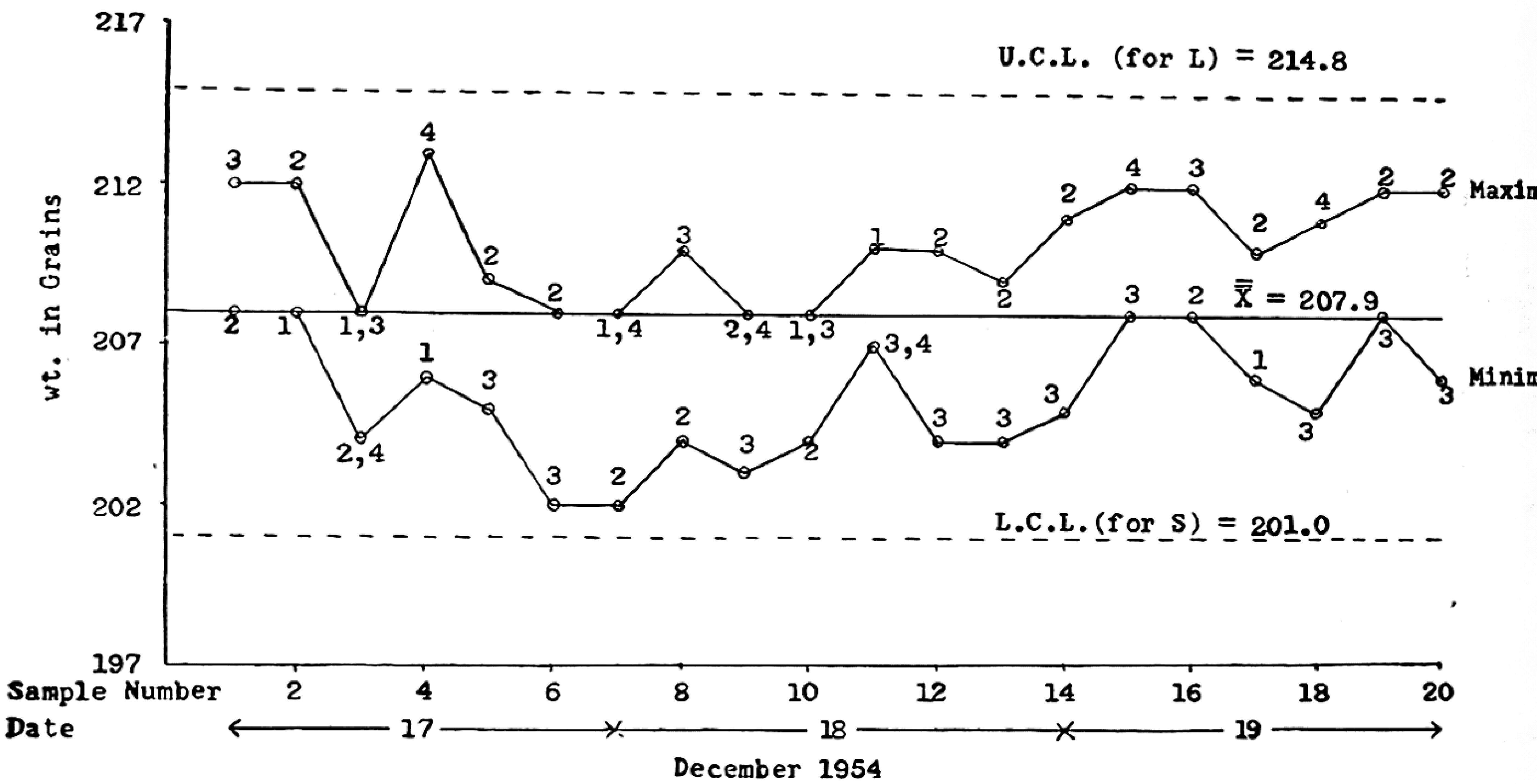
Thus it will be possible to treat similar groups in the same group control chart and yet retain all the important informations needed. The same method can be extended to the case of similar groups, even when they are not all of the same size, when we understand that the main purpose of such a chart is to serve as an action-guide.

Control Chart for Maximum and Minimum

Generally from the draw frames one wrapping of 5 yards is taken from each of the deliveries. Such data can usefully be presented in the form of a " Control chart for the largest and smallest values " in a sample, as outlined by Howell.[1] He has shown that this is as powerful a control chart as the $\overline{X}$ and R charts put together.

CHART III

Process : Drawing (Deliveries : 4)
Mixing : 62s/80s
Characteristc : Weight of 5 yds. of sliver in grains



Everytime the wrappings are taken the largest or maximum (L) and the smallest or minimum (S) along with their delivery numbers, are plotted on the chart (see Chart III). If $\bar{L}$ and $\bar{S}$ are the averages of the maxima and minima respectively, then $M = \frac{\bar{L}+\bar{S}}{2}$ can be taken to estimate the population mean. However, we can draw the central line in the usual way at $\bar{\bar{X}}$ (average of averages). For all practical purposes the upper limit for the maximum can be taken as $\bar{\bar{X}}+3\sigma$ and the lower limit for minimum as $\bar{\bar{X}}-3\sigma$. Whenever the maximum goes above its upper limit or the minimum goes below its lower limit we have to look for trouble. Since the probability of the maximum falling below the mean level or the minimum above it is small, it will be worthwhile looking for trouble when one of the two happens. If the maximum and minimum go out of their respective limits simultaneously it can be taken to indicate an increase in the variability.

Conclusion

The above examples emphasise the need and utility of the group control chart technique in textile industry, after deciding the different types of grouping, viz., a group of machines, or a set of similar groups or a sample itself as the occasion might warrant. These three examples have been selected to cover in general the different types of problems that arise in the application of control charts in the textile industry.

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QUALITY CONTROL IN THE SPINNING ROOM

G. B. Desal

Spinning Master, The Maneklal Harilal Mills Ltd., Ahmedabad

I am speaking to you not as an expert critic but as one who has learnt the SQC techniques from ATIRA and is trying to make use of them. For the last two years ATIRA has been arranging courses of lectures on statistical quality control so that the technicians of Ahmedabad mills may know the methods and apply them in their day to day work. These classes were conducted by Prof. Ekambaram.

The problem of quality product is very important to every textile mill desirous of maintaining its status in the midst of competition from others. You very well know that in a buyers' market we are guided by the consumers and the consumers decide good or bad quality. They have no instrument to measure, but their practical experience acts as their measuring instrument. The sales department always considers the consumers' angle about quality.

Quality control from the manufacturers' angle is equally important because it helps in reducing waste, machine to machine and department to department. It helps in maintaining a standard quality of the product.

Variation in the characteristics of the product is common in any mass manufacturing process. Two products even from the same machine are not exactly alike, however refined the technique of production may be. Statistical quality control is useful to maintain the "Level of Quality" and control variability. It does not consider the articles individually but the "population" of such articles.

Every technician does quality control job in his own way ; it is not that he is not doing anything for obtaining quality in his manufactured product. But SQC is a powerful technique at his command to economise his efforts wherever they may otherwise be wasted and to give him good insight into his work.

Statistical quality control theory will help in ascertaining the level of quality and the inherent variability of a process. If the quality is directly measurable in some units it has been found that under maximum control, the pattern of variation of quality follows the Normal curve. By the use of control charts we can check whether this pattern of variation is held by a particular process or not.

Now let us see how statistical quality control is utilised in every department in spinning.

Raw Material: The quality of cotton should be checked for its properties i.e. staple length, fineness, strength, impurities, nep, colour and moisture content. For testing the above properties enough instruments are there.

In India cotton has no standard, the samples from the same district are not similar; not only that, but the cotton from the same village varies a lot. We cannot find fault with the farmers for this because they have to rely entirely upon nature. Now-a-days Government is trying to do its best in this direction, viz., standardising the cottons.

Secondly, I come to the mixing of different cottons in Mills. You very well know that two cottons of different characteristics are mixed, for example Surat or Vijaya and Vagad — one longer, the other shorter; one softer, the other harsher; one is clean, the other is dirty; one fine, the other coarse. While applying the quality control technique, we must not forget that uneven mixing will have its own effect on the final product. Here I must say that if the base is alright it will help a lot in manufacturing good quality product. In a mixing room we should not neglect humidity control, which helps in overcoming static electricity trouble while working.

After the mixing room comes the blow room. You all know the importance of uniformity in weight per unit length of the product at every stage of yarn manufacture. To achieve the greatest uniformity in finished product, tolerance limits are specified at various stages. In the blow room we have to control the weight of laps and wrappings. We can maintain control charts for lap weight and wrappings. When points fall out of control limits we have to look for the cause. If the average and range are within their respective limits it indicates that the process is under control. Points beyond control limits are due to assignable causes and not due to chance causes. We have to find out the causes and remedy them from such charts. We can calculate the limits for rejecting individual laps too and these can be substituted for ad-hoc limits based on experience. In the carding department regular collection of waste figures is important. If the waste is controlled, it will to some extent reduce the variation of wrappings. Grinding and gauging are important. As card setting plays an important part in controlling waste percentage and in reducing neps, whenever cards are ground and gauged, we can study their effect by taking observations on wrapping, waste, nep and foreign matter. Regular statistics on these will be of great help in arriving at optimum settings card-wise.

On the combers we have to control waste percentage and also the variation of the combed sliver. Waste has to be controlled comber-wise and head-wise. Within a comber analysis of wrappings for statistical significance will also throw light on the working of combers. We can maintain control charts on draw frames to control variations of wrappings. Alternatively we can collect observations and test equality of variances from delivery to delivery and the reduction of variation from passage to passage.

On the fly frames and ring frames data on end breaks can be collected to study the general breakage rate and to isolate machines giving excessive breakage. Also charts can be maintained to study the variations in wrapping from machine to machine and from time to time as well.

Snap reading observations reveal the causes of loss in efficiency in the department and can be used as prompters of action.

Thus control charts and properly collected statistics on waste, breaks, efficiency etc. can be used to give us a good picture of the working of the department. The figures reveal the facts as they are. Our experience will guide us in taking action on them. For most of this work it is not very essential to have highly qualified staff. One or two men of average intelligence with proper training can do a lot of work after some time.

Shri Ambalal Shah (Technical Adviser, The Jehangir Vakil Mills Ltd., Ahmedabad) : I would like to point out some snags in the present method of applying control charts. The necessity of controlling the raw material has not been realized fully. Before applying control chart techniques in the later processes the quality of the cotton has to be controlled and standardised. This would go a long way towards the success of the quality control system. Also the nature of the blow room machinery is such as to limit any effective control of the variation within a lap.

I would like to know whether members of the Quality Control Group have made any attempt to control neps at drawing and subsequent stages.

I take this opportunity to express my appreciation of the work done by the Quality Control Group in bringing about a better understanding between the technicians and the statisticians.

Shri Jayant Purohit (ATIRA) : On behalf of the Quality Control Group, I would like to bring to the notice of Shri Ambalal Shah that a study of nep counts at various stages from bale cotton to card sliver has been made by some members of the Spinning Sub-group of the Quality Control Group. Results of these studies have been published in the Newsletters of the Group.

Shri R. Rajagopalan (ATIRA) : I wish to point out that ATIRA has conducted a systematic study of neps from carding to ring spinning, too. Reports on such studies have been sent to mills concerned.

Shri S. N. Bhaduri (ATIRA) (in a later communication to Shri Ambalal Shah): It is generally known that neps are formed during the blow room processing and are removed partially at the carding stage. This has been confirmed by studies by statisticians in mills and by ATIRA staff. The necessary steps for reduction of neps must therefore be taken in the blow room and at cards. Investigations towards this end are in progress in various mills.

Shri T. A. Subramaniam (ATIRA) : I have one comment to make on the control chart for minimum and maximum sample values. The situation in which Howell has suggested the use of this chart is different from the one in which Shri Sreenivasan has made use of the chart. Howell's assumption is that the values in the sample are from a single source of manufacture and therefore the assignable causes of variation are attributable to the single source whereas the four deliveries in drawing are four different sources of manufacture. As such the assignable cause of variation in a particular case can be attributed either to the whole draw frame or to a single delivery.

Shri S. N. Bhaduri (ATIRA) : Whenever a chart indicates a point out of control the technicians check the whole draw-frame as well as individual deliveries and therefore the chart is useful from both the points of view.

Shri L. R. S. Menon (Statistician, New Shorrock Mills, Nadiad) : I would like to know whether the control limits would be valid even when we know that the sources of manufacture are different.

Shri K. G. Reddy (Statistician, Jehangir Vakil Mills, Ahmedabad) : The assumption in keeping a control chart is that all deliveries have the same average and range of variation and that is why even when the sources of manufacture are different, the chart will bring out delivery differences.

Shri S. S. Trivedi (Manager, The Ahmedabad New Textile Mills) participated in the discussion.

Shri Champaklal Nathalal (in his concluding remarks) : On behalf of the Quality Control Group I thank heartily all those who read the papers and participated in the discussion. It is also my pleasure to express my gratitude to Dr. Shewhart to have honoured the deliberations with his presence. I am sure this evening's symposium and Dr. Shewhart's visit to Ahmedabad will give a great filip to our activities.

SESSION III

"Application of Quality Control Techniques and Design of Experiments in Textile Industry"

[Held in the Physical Research Laboratory Auditorium on Saturday, 1st January, 1955,
Shri S. N. Bhaduri in Chair]

APPLICATION OF CONTROL CHART TECHNIQUES IN MECHANICAL PROCESSING IN THE AHMEDABAD TEXTILE INDUSTRY

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The first attempts at the application of statistical control chart techniques in textile processing, in an organised way, in mills in Ahmedabad, were made over five years ago. Within a short time, other statistical methods like systematic collection of data, tests of significance, regression analysis and analysis of variance, to name only the principal ones, began to be gradually made use of in mill work. Even so, initially, the application of control chart techniques received a greater stress and had also been the main plank for the development of quality control through statistical methods in the Ahmedabad textile industry. Now, in many ways, the record of work done by the statistical sections of several textile mills in Ahmedabad is by no means a poor one. This paper is the result of a re-examination of the five years of activity, in the field of statistical control chart techniques, in mechanical processing sections to seek answers to questions like whether these techniques have been of real value and why uniformly in all mills where statistical sections have been started, the walls of the statisticians' rooms do not bristle with $\overline{x}$, R, p and c charts.

Are Control Charts Useful ?

In an effort, such as the present one, at an evaluation, it is essential to consider the basis for doing so. When do we say that a control chart is of value ? Or in other words what are all the objects of keeping control charts ? According to Ashcroft[1] the technique of keeping charts is to have a record of the quality characteristic and, consequently, to use the chart record as a basis for action with regard to production procedure. However, probably because of the great difficulty in meeting the challenge offered when trying to restore a state of statistical control, greater importance has come to be attached to the utility of the charts in indicating that action should be taken when plotted values fall outside control limits. Due to this charts which have met Ashcrofts' criteria have been mistakenly regarded as of no use owing to the fact that restoring the state of statistical control often been cumbersome. It is our view that it is equally, if not more, important to know that a production process at any particular moment has been under a state of statistical control and that no action need be taken and no effort need be made to change the state of affairs.

We say this particularly because the action often contemplated by the technicians when products from a machine are allegedly exhibiting a below or above-par average level or greater variability include costly items like changes of machinery, cotton, or attachment of various devices of mostly uncertain value. If it were only possible to work out the economic aspects of the loss due to inability to track down assignable causes of variation and the loss due to ignorance of the fact that a process is working under a state of statistical control, it may well turn out that the latter loss is the larger one in several cases. We have ventured to advance these arguments to emphasize the fact that inability to track down assignable causes quickly, as is frequently experienced in textile processing, is no reason for despondency. Actually the purpose of the control chart, when points go out of control limits, ends with indicating that decisive steps need be taken. If technical knowledge is not sufficient to enable a proper choice of the type of action needed to bring a return to the state of statistial control, then the application of the control chart technique need in no way stand discredited.

One may also make an evaluation of the utility of the control chart techniques in textile industry from another angle. What are the benefits that can be expected out of keeeping a control chart at any stage? A. D. Anthony and R. H. Souther[2] have listed more than ten benefits that can accrue from control charts. Some of these are too well-known to bear any repetition. Of these the benefit of providing criteria for immediate action to adjust machines is only one. In a particular case, this apparent benefit may not materialise owing to failure of methods of detecting defects in the machines. Even then the benefits of efficient methods of presenting data by these charts, of improved relationship between heads of various departments in mills, of holding closer tolerances, of being in a position to locate trouble more quickly continue to accrue. All these benefits often are well worth the trouble of keeping the charts. The evaluation of the control charts should not, therefore, be confined to their utility in any narrow aspect but in a general way. Anthony and Souther point out that in several mills control charts are maintained on card sliver, drawing sliver, roving and yarn and this combination of charts in these places have helped to assign the source of variation in the manufacture of yarn more definitely to weight of card sliver, roving etc. It might well have been that if the control charts had been discarded because the assignable causes for variation in any particular case in any chart could not be tracked down, such a benefit was never achieved.

A Few Limitations in the Use of Control Chart Techniques Do Not Lessen their Utility

We now turn to the next question as to why, if control charts are always useful, they are not as commonly used in the Industry as they should be. One explanation is fairly common to textile industry. As O. P. Beckwith[3] has pointed out the arguments for adoption of methods and processes designed to give more uniform product are somewhat abstract. As the consumer does not subject the cloth to immediate quantitative evaluation of quality and therefore to any systematic acceptance or rejection, any increase in uniformity of a product from 10% to 5% in say fabric strength is not readily discerned by him. Under these circumstances the importance to management of using quality control charts as rational basis for action directed at the producing or engineering functions, is only secondary. Another reason is that the statistical staff in mills when expected to keep control charts in various stages and also simultaneously to carry out planned and statistically designed experiments have naturally, under the stress of constantly requiring to convince their employers of the utility of their very existence, turned greater towards performing this latter function of theirs more efficiently which thus enabled them to dangle before the employers results achieved alongside spectacularly.

A peep into the life of control charts in several characteristics in many mills reveal that often the control chart techniques were started very enthusiastically till a stage came when the assignable causes could not be traced to any particular fault in the process. At this stage doubts have often crept in as to the source of action that should be taken. The control charts, under such circumstances, have been made the victims not infrequently. To us it appears that courses other than discontinuing a control chart are open when data showed lack of control and there is no reason to explain the points out of control. One might accept the value of σ obtained from the data, and set up control limits with the realisation that the process is uncontrolled. If any tentative limits had been used to start with they could very well be continued till the causes of variability are found and removed. It is our view that there need be no hesitation in continuing the trial limits or fixing limits from uncontrolled data temporarily even if such limits had to continue for many months. The principles of control chart application do not rule out such a procedure.

An argument quite frequently advanced in textiles is that assignable causes of variation in any sequence are sometimes erratic. On account of this, if the control chart in a subsequent sequence showed lack of control an investigation in the earlier sequence to find causes for this might well be possible only long after the assignable cause has done its damage. Though this argument appears valid in its limited sense it should not again make one dispirited in hunting for assignable causes. We have to bear in mind that not all assignable causes are erratic and a few of them could be of a fairly specific or stable type, like an operator changing a toothed wheel from 55-teeth one to 57-teeth one instead of 56-teeth one. If one were to find that the assignable causes have vanished before being tracked down it is only a happy and acceptable state of affairs. The trouble has corrected itself and thus have saved us the bother of spotting it. We also have the assurance that the process has become trouble-free. If, while continuing the chart, such erratic causes appear too frequently they only add to the importance of a general overhaul of the machinery or some other detailed study.

Scope of Future Work

Having put forth our view that a few limitations in the application and use of control chart techniques in the textile industry should not lessen their general utility we put before us the question : What is the scope of work that has yet to be done with regard to progressive utilisation of the control chart techniques in our industry. A greater realisation by the management and technicians in the industry is needed of the fact that statistical quality control derives its importance from its scientific basis. It is not merely enough to realise that quality is important, that quality uniformity is desirable but it is also necessary to feel that the only sound basis or method offered towards attaining these goals is through control chart techniques. Action on any other basis is quite likely to be misleading, ill-time or unwarranted.

The possibilties of control chart application are almost legion. Unfortunately, however, no critical examination has so far been made as to what all characteristics pay back the cost of the keeping of charts on them or alternatively given a certain amount of money what priorities should be given to the different characteristics for maintaining charts on them. Lack of precise information on these cost aspects have been a big boulder in the path of progress. One has naturally to fall back on the relative importance of these felt by experience. Often the importance of keeping a chart on characteristics like end breaks in ring spinning are directly not economic as much as political. Knowing that the level of end breaks as read from the chart has been steady, the bugbear of complaints of sudden increases in breaks etc., made by workers aided by Unions could be avoided. Here again an all-round realisation by management, technicians and labour that one could take care of only average levels of working within certain limits and cannot do very much regarding any individual point falling away from the average levels, is worth trying to achieve.

Summing up, the application of the control chart technique for full realisation of their benefits offers continuous challenges on the organisational, statistical and technological aspects and a pre-requisite to progress in this field requires that these are accepted and met patiently and perseveringly.

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Shri R. Rajagopalan (ATIRA) : In textiles, the variation in back stuff plays a very important part and unless a check is kept at each stage it is not possible to trace variation in one process to the variation in the back processes.

Shri V. D. Pendse (Statistician. The Rohit Mills, Ahmedabad) : I agree with Shri Rajagopalan that control charts have to be maintained in all sections. In fact as long as operatives can not maintain continuous charts themselves, control charts introduced intermittently would not be of much help.

Dr. Shewhart : I would like to know whether anyone has attempted to assess how much saving has been effected by introducing control charts.

Shri S. N. Bhaduri (ATIRA) : In textiles no product is rejected as unprocessable as it is done in engineering industries. A control chart in textiles helps in reducing the variation in material processed or for reducing breakage rate which indirectly helps in saving cost of production by rational use of material, manpower and machinery. If, for example, the percentage of rejected laps in blow room is reduced it does not make a direct saving because the rejected laps are not sent back as waste but an indirect saving is accrued because the trouble of re-processing the rejected lap is avoided.

Shri Rama Rao (Manager and Weaving Master, The Commercial Ahmedabad Mills) : I may amplify Shri Bhaduri's remarks by another example. By introducing control charts at various stages of manufacturing in my mill we could reduce the damages in finished cloth from 14% to 8%. Now this could not be attributed directly to the control chart kept for damages in finished cloth. It was becaues of the check on breakage rates and variation introduced from the initial stages of manufacturing.

Dr. Shewhart : An annual estimate of the savings made by the introduction of SQC is very essential to bring out the importance of SQC.

DESIGN OF EXPERIMENTS IN TEXTILE RESEARCH

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" Experimental observations are only experience carefully planned in advance and designed to form a secure basis of new knowledge "....R. A. Fisher.

In industry, as in other fields, acquisition of new knowledge is essentially through experience and experimentation. Not that experimentation is fundamentally different from experience but it is only the setting up of suitable conditions which might result in new experience. The statisticians' role lies in contributing towards making such conditions more effective by virtue of which experiments will become more fruitful. As such any experimentation involves

1. Statement of objectives and defining the experimental treatments,
2. Designing the experiment,
3. Outlining the method of analysis.

The execution of these steps in textile research presents peculiarities and difficulties whch it is the purpose of this paper to state briefly.

Statement of Objectives and Defining the Experimental Treatments

" The null hypothesis must be exact, that is free from vagueness and ambiguity, because it must supply the basis of the problem of distributions of which the test of significance is the solution "....R. A. Fisher.

The statement of objectives may be in the form of (i) questions to be answered, (ii) hypothesis to be tested and (iii) effects to be estimated. The formulation of the questions to be answered is mostly technical and can be done precisely. This will lead to the statement of the treatments to be assessed. But there will be more than one characteristic to be considered in the assessment of such treatments, which in turn will involve a number of hypotheses to be tested. For example, if the point under study is to decide which of two methods of preparing the ribbon laps fed to the combers is better, the treatments to be compared are the two methods of lap preparation. But one has to take into consideration numerous characteristics from the comber stage to the loom, such as the comber waste extracted, strength and uniformity of yarn and breaks at various stages etc. This leads to setting up of a number of hypotheses at each stage which might lead to ambiguities in interpretation which will be mentioned later. Naturally under such circumstances there will be more than one effect to be estimated. For the selection of appropriate characteristics it is important to understand clearly the role played by each treatment on the characteristics to avoid ambiguity in interpretation.

"It is an essential characteristic of experimentation that it is carried out with limited resources and an essential part of the subject of experimental design to ascertain how these should be best applied"....R. A. Fisher.

Though it is truism to say that a well planned experiment leads to more reliable results more economically than one arranged without full consideration of the disturbances and errors involved, when one tries to plan an experiment in a mill under conditions obtaining there, practical considerations become as important as the statistical considerations, as interference with regular production, the labour involved in making frequent changes put much limitation on the appropriate design to be chosen for a particular situation.

The methods of increasing the precision of an experiment may be broadly grouped into three types as :

(i) Increasing the size of the experiment through the provision of more replicates,

(ii) Refinement of the experimental technique,

and (iii) Proper handling of the experimental material to reduce the effects of extraneous variability, not relevant to the treatment comparisons.

(i) Increasing the size of experiment can be achieved by two ways, namely either by having more replications (blocks) or by increasing the number of readings within a plot. Increasing the number of blocks may or may not be possible depending on the type of experiment. Generally when we require a number of machines to increase the blocks, as it would hamper the production of the department to a considerable extent, the former method offers very little scope. As, for example, when the material is run on fly frames, it will not be possible to get more than one frame for the experiment. However it may be possible to have a number of sides in the ring spinning department kept apart for the experiment. The difficulties of handling a large volume of material further limits the size. This is to some extent compensated by the possibility of having number of observations from the same plot. If the characteristic under study is strength or uniformity of yarn, number of samples can be collected from each plot since the plots will be spindle sets.

(ii) Refinements of experimental technique, namely, the use of more appropriate design, though they may lead to increase in efficiency. are not always found practicable. Suppose we are interested in comparing three mixings, spinning to the same count as in small sample spinning technique it will be better to run them simultaneously at each stage of the process. For this a randomised block design with a block size of three will be appropriate. This would mean that we will have to run the three materials everyday, each day being a block and the experiment being repeated on sufficient number of days to get enough blocks. But the difficulty of preparing the mixings and following the three treatments restrict us to the use of a balanced incomplete block design in which pairs of treatments are run everyday. A knowledge of the relative importance of the extraneous variability will help in the choice of the appropriate design. But it is not always possible to have such clear cut knowledge, as a type of variability once found in our experience to be significantly unimportant turns out in another circumstance to be significantly important. In such cases where we lack any precise idea about the relative importance of variabilities it is better that we choose Latin Square or other similar designs to be on the safe side.

(iii) The grouping of experimental material such as machines, spindle sets etc. to form homogeneous plots offers many advantages. If the experiment is to study the effects of two different speeds of the licker – in of a card on the cotton processed with regard to card waste and neppiness of card web we can select two cards of fairly the same age and further reduce differences between them by keeping suitable settings. This generally applies to other departments as well. In this case the general absence of interaction between treatments and machines in experiments we have done so far is worth pointing out, since generalisations and extensions of the results of limited experiments to other machines are more valid. Selectivity in the material which limits the validity of generalisation of conclusions from a typical sample to the entire population is difficult to avoid when experiments are conducted in the field of economics or sociology. The successive application of treatments to the same subject (viz., machine) is also possible in textiles because of the absence of persisting effects of the treatments. This again is not possible in biological and psychological experiments.

Outlining the Method of Analysis

" In considering the appropriateness of any proposed experimental design, it is always needful to forecast all possible results of the experiment and to have decided without ambiguity what interpretations shall be placed upon each one of them."....
R. A. Fisher.

As it has already been pointed out, the comparison of two or more treatments lead to the study of a number of characteristics and hence to setting up of number of hypotheses. Though it is possible to state the null hypothesis unambiguously it is not always possible to state the interpretations that shall be placed on each one of the results, since tests on different characteristics may bring out contradictory conclusions. Technical background is essential in choosing which of the tests shall be taken as more decisive. Nor is it always possible to assume the exact distribution on the basis of the null hypothesis. In this connection end breakage data though presumably expected to follow Poisson distribution do not always do so.

Whatever be the design it is generally possible in textile experiments to get more than one reading from each plot. But suitable methods of analysis are yet to be devised in some cases.

Because of numerous observations for each treatment, small practically insignificant differences turn out statistically significant ; but we cannot decrease the number of observations as it may result in certain instances in lack of proper representation to different types of experimental material. The solution to this difficulty, perhaps, is to prepare tables for higher significant values.

In this connection though " the construction of confidence limits may add something to the interpretations of a test of significance " (Cochran and Cox) such limits are neither very reliable nor consistent. A confidence interval for the difference between breakage rate with two treatments established in one experiment may not hold good for a long time. This may not be due to chance causes alone but due to a decrease or increase in the general breakage rate of the department due to some assignable cause, which it may not be always possible to point out.

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SOME STATISTICAL TECHNIQUES USED IN TEXTILE INDUSTRY

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Introduction

One important achievement of ATIRA's work in Ahmedabad is an increasing awareness among the technicians of the Ahmedabad textile industry for an experimental approach towards problems arising in the day to day working of mills. The importance of a scientific approach in taking decisions or drawing conclusions from quantitative estimates rather than from guess work, is realised far better today than a few years back. It may be still difficult for the technician to understand the complicated statistical techniques used in the analysis of data but the rationale behind taking decisions on the basis of facts and figures is becoming undoubtedly acceptable to him.

Systematic Collection of Data

It is true, one does not have to take important decisions every day in a mill but a number of minor changes and actions have to be introduced from day to day so as to meet the demands of production and for maintaining an expected quality of the product. There is no need to exaggerate the importance of such changes and actions. Systematic collection of data is of great help in taking such decisions. In the carding section, for example, the technician has to keep a constant check on various characteristics like percent waste extracted at different points, trash content removal, nep count etc. The technician felt at one time that with his experience he can decide a certain set of speeds and settings and a maintenance programme which would inevitably lead to correct results. If at all he checked the results any time by actual observation, he would just go to the department and see a few cards to decide whether trash removal, nep count and waste are satisfactory or not. Such an unscientific procedure at times led to wrong conclusions and no action would be taken when it was essential and sudden changes would be made without having sufficient cause. To day, the technician does not accept a vague terminology like " satisfactory nep count " " good cleaning " or " low breakage rate ". He takes for quantitatve estimates for each characteristic based on a sufficiently large number of observations taken in a systematic manner. Another important use of the systematic collection of data is that the quantitative estimates make possible a comparison with the working of another mill having more or less similar conditions. It also gives the relative importance of any characteristic in the sequence of the process. Textiles being an industry with a continuous process, there are various characteristics of products which have to be compared from process to process. Increase in variation from carding to ring spinning, increase in neps from bale cotton to carding, removal of trash from cotton to carding, removal of weak places from winding to warping, observations taken on, — characteristics in successive departments give such an idea as to where immediate attention needs to be given. Systematic collection of data gives us the average quality and range of variation of various characteristics of the product.

Machine Differences

As mentioned above once the systematic collection of data gives an overall picture of the department the next question arises whether all machines working in the same department are having the same average quality and range of variation or not. The textile process being a continuous one, a single machine in any department has to be fed by material produced on various machines in the previous section. Therefore not only the average quality but also the range of variation needs to be uniform from machine to machine in the same department. When it is desired to compare the machine to machine performance in a spinning department, for example, it is first decided as to how much difference in the mean strength of two machines will be regarded as of practical importance. With the knowledge of the coefficient of variation of strength one can find out the number of tests necessary to bring out the necessary difference in average strengths of two machines as significantly different. The analysis of variance separating the components of the total variation into parts contributed by the differences in machines and chance fluctuations, indicates whether the differences observed in mean strengths of the machine can be ascribed to chance causes or whether the differences can be regarded as due to a real difference in the performance of various machines. As already mentioned a uniform range of variation for strength from machine to machine is equally important. Bartletts' test for the homogeneity of variances leads to detecting machine giving material more variable than others. The machine to machine differences in characteristics like breakage rates which follow a Poisson distribution are brought out by a χ^2 test. Such information regrading machine differences arising due to factors operating over a long period is very useful in maintaining a uniform quality and range of variation in each department. Collection of data for detecting such differences takes two to three weeks and therefore only those causes which continue over a long period can be detected by analysis of variance or Bartletts' test or a χ^2 test.

While comparing a number of machines in the same department one has to take into consideration various characteristics of the same material. Corresponding to each characteristic of the material tested we arrive at a set of conclusions. Thus if data is collected for detecting machine differences in spinning on lea-weight, strength and breakage rate we have three sets of conclusions regarding machine differences, one corresponding to each characteristic. If the three sets corroborate each other there is no difficulty in interpreting the analysis but if the three sets lead to apparently inconsistent results it becomes difficult to interprete the overall picture because such characteristics are inter-related.

Inter-related Characteristics

When data is collected on two inter-related characteristics a knowledge of the relationship existing between the two characteristics sometimes leads to useful information. For example, it is well known that as stoppages on a machine increase, the efficiency of the machine decreases. But can we therefore say that, if there are 10 breaks per 1000 yards per 400 ends in warping and the loss in machine utilization is 40 %, 4% machine utilization is lost per break? The exact relationship between the breaks and machine utilization has to be found out by taking pairs of observations. When the relationship is found one can predict how much increase in machine utilization can be expected if the breakage rate could be reduced by better maintenance or better quality of the material fed. Various characteristics in different textile sections are known to be related to each other; but unless a simple relationship exists between such characteristics no good use can be made of such an information. Technically the most important but perhaps the most complicated is the relationship between count and strength of yarn. Broadly the strength of yarn increases as the count becomes coarser or the weight of yarn per unit length increases. Hence the comparison between mean strength of two yarns spun by two machines neglecting the mean counts spun by them would be incorrect. But when the mean strengths of two machines are compared, it is expected that the mean counts spun by the two machines would not differ by more than two or three counts. The relationship between count and strength in such a small range of counts has been shown to be

$$C_2 S_2 = C_1 S_1 - K (C_2 - C_1)$$

where C_1 is the observed count

S_1 is the observed strength

C_2 is the nominal count for which the strength is to be corrected

S_2 is the corrected strength

and $k = 0.7 (74 - C_2)$

It has not been possible to test the difference in the quality of two yarns taking into consideration both count and strength. Generally the mean counts are tested first and if the mean counts are not significantly different, the mean strengths are tested without correction. However, if mean counts are significantly different, one has to test the corrected mean strengths. For this purpose it is necessary to obtain an estimate of the variance of corrected strength. The large sample approximation for the variance of the corrected strength is

$$V(S_2) = \frac{1}{C_2{}^2}\Big[C_1^2\, V(S_1) + (S_1 + k)^2\, V(C_1) + 2\, C_1 (S_1 + k)\, \mathrm{Cov}\,(C_1, S_1)\Big]$$

The test for corrected mean strength thus involves the computation of the covariance of count and strength. With the same calculation would it not be better to test the two mean values of count and strength simultaneously by Hotelling's T^2?

Another difficulty in making use of observations in textiles is that the variables under observation happen to be Poisson and it is not known whether a linear regression between two variables one of which is Poisson could be found by the method of least squares.

Length of Specimen

In addition to controlling the average quality and variation within a department, one has to make a comparative study of tht vaiation from process to process. The length of wrappings in different spinning sections needs, therefore, to be decided in such a manner that the measure of irregularity obtained from process to process remains comparable. It has been shown that if N strands from one process are fed together and drafted with a total draft D, then the coefficient of variation of wrappings of length $\frac{L}{D}$ from the process before drafting, denoted by $CV_B\left(\frac{L}{D}\right)$ and the coefficient of wrappings of length L from the process after drafting, denoted by $CV_A(L)$ have the relation.

$$C.V_A(L) = C.V_B\left(\frac{L}{D}\right) \div N$$

By convention, the interest is in controlling the count variation or the variation in the weight of 120 yards of yarn. So far, the length of wrappings to be taken from any section has been fixed arbitrarily as a result of which the values of C. V. from process to process are not comparable. If the length of wrappings from any process is decided by the formula :

$$\frac{\text{Length of wrapping in the next process,}}{\text{Total draft in the next process,}}$$

the length of wrappings to be taken in the first or second passage of drawing for comparison of C. V. would be too small for accurate weighing. The length has also been decided, at times, by the formula :

$$\frac{\text{Length of wrapping in the next process}}{\text{Total draft in the next process}} \times \text{Doubling in the next process.}$$

This formula makes it possible to have in all processes wrappings of length sufficiently large for accurate weighing. The expected values of C. Vs. of wrappings from the processes before and after drafting, where the length is decided by the above formula, have been assumed to be equal in the absence of any knowledge regarding their definite relationship.

Snap Reading

When it is desired to estimate how much of the total productive capacity of a department is lost due to varoius causes, the estimates can be found in two ways. One can time the machines and record the duration of stoppages during fixed intervals. But this is obviously a tedious work and very few machines can be observed at a time. Moreover if one wants to estimate the time spent by a worker on various jobs, it is not desirable to time the worker because it may lead to under estimates when the worker becomes conscious that he is watched. A snap shot of the whole department taken at any instant gives indication of the losses in output due to stoppages of looms corresponding to various causes. If such snap readings are spread uniformly over the whole day, the estimate obtained from the proportion of machine stopping due to any cause would estimate the proportion of total time the machines stop due to that cause. Snap readings taken for recording the various jobs with which the worker is busy would give estimates of the proportion of total time spent by a worker on various jobs. It has been shown by the Shirley Institute that there is a high correlation between the estimates of stoppages obtained by snap-readings and continuous observations. Thus instead of spending a number of hours in continuous observations over a few machines, a number of snap can be made over all the machines and more reliable estimates can be obtained. The estimates of efficiency obtained by snap-reading have been found to be in good agreement with mill efficiency figures unless there are causes due to which systematic stoppages occur on the machines. The number of snap-readings (N) necessary to get an estimate of efficiency with a given accuracy and confidence is calculated on the assumption that the proportion of machines stopping at any instant follow a Binomial distribution. But except in loomshed the actual variances of the proportions have been found to be two or three times the expected variance $\frac{p(1-p)}{N}$ where p is the proportion.

Machine Interference

In textile industry a number of machines or units are allotted to an operative. These machines stop from time to time and whenever a machine stops the operative has to perform some work on it before it can be restarted. While the operative is attending to one machine, one or more of the remaining machines allotted to him may stop and have to wait restarting till the operative is free to attend them. Thus there is a loss in productivity due to this cause generally known as machine interference. If more than a due number of machines are allotted to the operative the machines remain idle and there would be a loss in total productivity and similarly if less than due number of machines are allotted the worker would not have the standard work load and he may remain idle resulting in a loss in productivity. The optimum number of machines to be allotted to a worker for given workload can be worked out theoretically.

Market Research Survey

The experience of the post war years when the Indian Textile Market was flooded with varieties of cloth which had no demand and had shortage of other varieties which were very much in demand has clearly indicated the need for studying in a scientific manner what varieties of cloth are in demand in what quantities.

Reliable information obtained from a market research survey regarding the preferences of consumers for textiles classified according to count, colour, lustre, finish design etc. will go a long way in planning the production and distribution of varieties of cloth preferred by the consumers.

Such a survey will have to investigate the controlling influences in the chain between the producer and consumer and how these factors decide the varieties and amounts of textiles manufactured. Another important study in such a survey will be to investigate the channels of communication through which the consumers' preferences are passed on to the producer and further to examine whether the existing channels are operating or can operate satisfactorily. Apparently the production of different varieties in different counts is decided at present on the basis of inexact knowledge of the fluctuations in demand with the help of unreliable information and later on the producer influences the dealer to sell whatever is produced.

The necessary information in such a survey will have to be collected from three sectors. The first sector will be the producers from whom will have to be collected information regarding

(1) the production capacity of their units

(2) methods of studying demand and planning production of different varieties

(3) the organization for distribution and sales, etc.

From dealers information will have to be collected regarding their organization and policy of sales and purchases, method of studying consumer preferences and conveying them to the producer. From consumers information will have to be collected regarding their propensity for consumption, their preferences classified under various items etc.

Since the survey will have to cover a very wide area for eliciting information and since methods of market research suitable for the patterns of production, distribution and purchsae of textiles existing in India have not been developed, a pilot study for a small area of one district is under consideration. The purpose of such a pilot study will be to establish a methodology for market research surveys suitable to Indian conditions, rather than to seek facts as such.

The market research survey will be of great help to producers in planning their production so as to meet consumer demands avoiding the production of too many sorts at the same time and the frequent changes in sorts. It will also help in estimating the effective demand for the textiles manufactured by the handloom industry as compared with those manufactured by mill industry.

Shri N. Subramaniam (ATIRA) : Regarding the problem raised in the paper about the interpretation of different sets of conclusions corresponding to different characteristics of the same product I would like to make a comment. The strength of yarn for example does depend, but not entirely on count of yarn, twist and other characteristics of yarn also affect strength. Similarly breaks do not entirely depend on strength but also on other factors which need to be taken into consideration. In short the analysis of data made on various characteristics needs to be interpreted with a technological perspective. When this is done the apparent inconsistencies can easily be resolved.

Shri Sahasranaman (Western Indian Group of Mills, Bombay) : The formula for corrected strength given by the Central Cotton Committee could be used universally only if the relationship between strength and count were uniform. I remember one instance where the regression coefficients of strength on lea weight for the same count were significantly different from machine to machine. I would like to know if strength and count are not significantly different between three treatments but the regressions are significantly different, how can one choose between the three treatments? If mean count and mean strength are not significantly different, from a practical point of view, there is no reason why one should test whether the regressions are equal or not.

Shri Purohit (ATIRA) : If corrected mean strength was to be tested one has to find the covariance between lea weight and strength values. With the same calculations, one can test whether the relationship between the count and strength is linear or not and if it is found to be linear is it not better to make use of this information rather than using an empirical relationship for correcting strength?

Shri D. V. N. Sarma (ATIRA) : From a practical point of view a difference in strength of less than one pound will not be of any importance and any difference of more than a pound in corrected mean strengths will be brought out in most of the cases (the sample size being 150) even if we use the variance of the uncorrected strength as the variance of corrected strength. As such the necessity for working out the variance of corrected strength will arise very rarely.

Shri S. N. Bhaduri (ATIRA) (in a later communication) : Combining the tests on count and strength into a single Hotelling's T^2 test is not appropriate for count differences as such do not measure the difference in spinning quality between two treatments. The count difference is an extraneous variation and therefore the strengths have to be adjusted for differences in count. If an alternative to the use of the existing correction formula is found necessary the technique of covariance analysis can be tried.

Editorial Note :

In the paper by Mr. Purohit in the section dealing with length of specimen, the assumption regarding equality of the C. V.'s of wrapping of length $L/D \times N$ before drafting and L after drafting is valid if correlation between the weights of N consecutive pieces of length L/D before drafting is zero. This will not be so for any length L/D. In fact for smaller lengths L/D, the correlation effect will be present and will have to be estimated for different lengths at different stages of production.

QUALITY CONTROL IN CHEMICAL PROCESSING

T. R. Chandrasekhar and M. H. Gandhi,

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During the last five years, ATIRA has been successfully employing the quality control techniques in textile industry. A number of mills have appreciated the usefulness of these techniques and at present many mills have got full-fledged quality control departments. However, the tendency during the last five years was to concentrate on mechanical processing. The reasons are obvious, because the quality control techniques have a direct application to mechanical processing, but when one comes to chemical processing, the quality control techniques do require some modifications. For example, control charts have been kept in the spinning and weaving sections on important characteristics such as weight of finisher lap, wrappings in carding, combing, drawing, etc. weight and strength of certain yards of yarn in ring spinning, end breaks at various stages of manufacture etc. In all these cases certain objective tests are possible and by using simple instruments one can get well defined measurements on the characteristics under consideration and the time taken is very short. However, this favourable situation is not available in chemical processing because the quick methods of measuring the characteristics are more subjective than objective. For example, in dyeing whether two different shades match or not, is subjective unless one uses some laborious and time consuming methods.

The first difficulty is about getting quick and easy objective tests to measure the characteristics in the chemical processing. The second difficulty is of getting proper random samples. When a certain length of cloth is being processed, it is not possible to take a random sample of cloth by cutting the required portion because, in that case, the cloth will be damaged. We have not yet succeeded in overcoming these difficulties but some line of approach which we feel can be adopted is outlined in the following sections.

The chemical processing comprises the following processes:

1. Slashing
2. Bleaching
3. Dyeing
4. Mercerising
5. Printing
6. Finishing

In slashing it is very common to use 3 or 4% more size than the optimum. (See ATIRA Research Note Vol. 1 No. 4). Further there are large variations in amount of size from beam to beam and within a beam. Hence a control chart at this stage on the size percent on yarn is very essential to know whether the beams have been oversized or undersized. The difficulty lies in not knowing the exact size percent of the yarn by a quick method. The current method of weighing beams in the mills has been shown to be not very accurate and the alternative method of laboratory testing is very time consuming. A quick and easy method of determining size percent has been given in the Textile World, March 1954, which need not be quoted here. It is very easy to get the size percent on the yarn in half an hour by employing the above method provided the stretch percent of yarn has been determined previously by accurate methods. At present we are conducting some experiments to determine the accurate method of obtaining the stretch percent and also see whether the method given in the Textile World is sufficiently accurate for mill work. After this we can keep control charts on the size percent on yarn.

Bleaching

Bleaching comprises of kier-boiling, chemicking and souring. Here, as mentioned earlier, it is difficult to have quality control in its strict sense, but still we can maintain some regular records. They will be useful in knowing the state of affairs in bleaching section. For example in the case of hypochlorite bleaching the following table will be useful.

TABLE I

Hypochlorite Bleaching

Date	Details of the cloth, yardage poundage	pH values at 1/4 hr. interval	Chlorine content at 1/4 hr. interval	Temp. at 1/4 hr. interval	Time of reaction	Whiteness of Fabrics A B C	Remarks

In the beginning one or two major sorts can be taken to keep records as shown above. The judgement of "Whiteness of Fabrics" will be subjective. We can classify the whiteness of the sample into one of the categories:

(A) Good
(B) Fair
(C) Medium

by comparing it with the standard sample.

Dyeing

As far as dyeing is concerned, the management purchases the dye-stuffs in lots from different sources. When purchasing the dye-stuffs, a concept of quality control can be made use of to, (a) match wide varieties of shades, select combination of dye-stuffs compatible but having similar dyeing affinities suitable for different fibres in use in the mill which will meet pre-determined fastness requirement commensurate with the end use, (b) use a variety of dyeing assistants and fixing agents which will not interfere with the subsequent finishing processes.

As in the case of bleaching information on important features can be kept in a tabular form, as given below :

DYEING OF VAT COLOUR
Kind of cloth or yarn and its quality :
Dyeing : Name of the dyestuff :
Process employed :

No.	Wt. of cloth or yarn	Standard shade	Amount of colour used	Amount of chemicals used	Temp. of dye-bath	Time of dyeing	Oxidation	Soaping	Shade obtained	Remarks

The collection of samples is difficult. It is not possible to cut samples at random as the cloth loses its continuity. Perhaps a strip of cloth of the same variety can be passed through dyeing machine simultaneously along with the other cloth at random intervals and these strips of cloth can be later examined in the laboratory or by some other method. We have not yet tried out this system anywhere.

Regular analysis of raw material and adhering to specifications for methods of processing would prove advantageous.

Mercerisation

In mercerising regular records if kept as indicated will be of great help.

MERCERISING OF CLOTH
Kind of cloth and its quality :

No.	State of cloth	Concentration of caustic solution OTW	Temp.	Time of contact or speed of machine	Caustic content of the cloth at the end	Degree of Mercerisation*	Remarks

* The concept of " Degree of Mercerisation " is still vague.

Printing

In printing the control charts can be kept on the number of defects per unit length of the printed cloth and the appropriate C chart can be maintained for these.

Finishing

Finishing is the last phase of several processes where the cloth is converted into a form acceptable to the customer. In finishing the management is interested in the homogeneous absorption of finishes by the cloth. A quality control chart was kept in a local mill, when the salesman complained to the Management that he was not satisfied with the amount of finishing given to particular type of shirting cloth.

The following is the procedure we adopted : The shirting cloth was to be 20 yards in length for each piece. So, we took 50 samples, each of 4 pieces as shown below :

CONTROL CHART IN FINISHING

Characteristic : Weight of piece of finished cloth :

Sample size : Group of 4

Sample No.	**Date**	**Time**	**Weight of piece**				**Average**	**Range**	**Remarks**
			1	2	3	4	$\bar{X}$	R	

Charts for $\bar{x}$ and R were plotted. Whenever the point was below the lower control level in $\bar{x}$ chart, usually it corresponded to a sample which had its length less than 20 yards. Some points were above the upper control limits and usually they corresponded to the samples whose yardage was more than 20 yards. In one or two cases, the samples remained in the finishing machine for a longer time due to stoppage of the machine. When these results were shown to the salesman he was satisfied with the uniformity of the finish given per yard of cloth. There may be some other causes which have to be investigated in further detail when a point falls outside the limits. An exchange of knowledge and discussion between the technician and the statistician will improve the situation and make the quality control techniques in chemical processing a success.

We do not claim to have done much work in this direction, but we have put before all of you some of our ideas and we would appreciate very much any comments and suggestions that you would like to make, because this is a subject which is still in an exploratory stage and it is subject to perhaps numerous modifications.

DISCUSSION

Shri S. N. Bhaduri (ATIRA) : I would like to know as to what quick tests could be used for testing the degree of mercerisation if a control at this stage is to be introduced.

Shri P. K. Chouthoy (ATIRA) : The Chemistry division of ATIRA is trying in collaboration with the electronics section to work out quick test for lustre which is one of the most important characteristics that measure the degree of mercerisation. Even these tests would take some hours by which time the lot under process would have already passed and improvements could be made only in the subsequent lots.

Shri D. R. Sharma (ATIRA) : The three characteristics, namely, barium activity number, deconvolution count and lustre number are independent to some extent and importance should be placed on one or the other of these characteristics depending on the end in view. For example, the barium activity number will be high and lusture number will be low when cotton is mercerised with low tension compared to those with high tension. The first criterion is suitable for the absorption of the dye etc. Mercerisation under tension is more important if lusture is the only criterion.

I would like to mention in this connection that instruments for measuring the lusture number are available.

Shri A. G. Chitale (ATIRA) : Since mills are interested mostly in the lusture number it would be sufficient if the samples are classified into three or four categories by comparing with a standard sample, as indicated for whiteness after bleaching.

Shri P. K. Chouthoy (ATIRA) : I wish to point out "Tendering" is an important characteristic in bleaching and data should be collected on this too.

SESSION IV

" Theoretical Statistics "

(Held in Physical Research Laboratory Auditorium on Sunday, 2nd January, 1955,
Dr. Walter A. Shewhart, in Chair)

A SAMPLING INSPECTION PLAN FOR BOBBINS

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" Quality Should be produced, not inspected into a product "......adage.

After the introduction of Control Chart techniques, statistical designs of experiments and systematic collection and analysis of data in the mills, the Statistics Department of ATIRA turned its attention towards studying the feasibility of introducing Sampling Inspection for the acceptance of Store items. Studies on end breaks in ring spinning and their causes revealed vibrating bobbins to be one of the major factors affecting breaks. In pursuance of this finding we conducted a number of experiments to study in detail the effect of vibrating bobbins. The results were unambiguous regarding the lowering of quality of yarn with vibrating bobbins, though the extent of such deterioration varied from mill to mill. We give below two typical figures.

Mill		1	2
Count		36s	44s
Vibrating bobbins as % of total		6.8	2.6
Breaks per 100 spindle hours in ring spinning	Vibrating	61.9	156.1
	Non-vibrating	28.9	17.7
Lea strength	Vibrating	50.9	47.6
	Non-vibrating	52.9	48.5
Winding breaks per 100 bobbin changes	Vibrating	30.3	56.2
	Non-vibrating	19.1	33.0

(All differences are statistically significant)

The vibration of the bobbins affect the working in subsequent sections, too, as is evident from the above table.

These experiments led us to make an attempt at introducing acceptance sampling for the bobbin to start with. Hundred percent inspection of bobbins is very time-taking. A mill buys on an average, at intervals of three months, and about 100 gross at a time. With the present method of inspection viz., running the bobbins on one side of a ring frame and observing by feeling, or with any other instrument like the "strobo-flash", the vibration, it would take anything, upward of 2 hours for 200 bobbins.

The text-book plans for inspection become inapplicable for bobbins because the fundamental requisite, that the LTPD or AOQL be much greater than the process average, is not met with. As a matter of fact, it has been our experience, that the process average may be as high as 10%, whereas, the allowable percentage, or, in other words, the percentage of vibrating bobbins that may be allowed to enter into the lots used, without appreciable adverse effects on the quality of the yarn, may be as low as 5%. This will mean, that, if we follow the classical method, all the lots will be rejected, leading to 100% inspection. An obvious remedy is to introduce Qualiity Control techniques at the manufacturing stage, or employ better methods of production. Our attempts at this are limited by the feeble influence we have over the manufacturers.

Hence we had to give the mills a suitable plan for screening out enough defectives from each lot, so that the outgoing lot will be of the acceptable quality. This will reduce inspection and at the same time, give us enough assurance against accepting bad lots.

In this connection an implied suggestion, for such a use of Sampling Inspection, for inspecting quality into the lot, by Sealy, in " A First Guide to Quality Control For Engineers " (p. 31) can be referred to. Suppose we get lots of size N with a process average $100p\%$. Let our allowable percent defective after inspection and replacement of all defectives met with during inspection, be $100p'\%$. The expected number, n, of items to be inspected from each lot to reduce $100p\%$ to $100p'\%$ can be calculated from the equation.

$$E\,(n) = N - \frac{Np'}{p} = N\left(1 - \frac{p'}{p}\right) \quad \ldots\ldots\ldots\ldots \quad (1)$$

This is true when $N \to \infty$. (N is quite large in this case)

In applying this basic method to the specific instance, we can incorporate a few useful modifications.

The inspection of the bobbins from each lot can be done in successive groups. Since it is not possible, in a mill, to get more than one side or at the most one full machine for inspection of bobbins, testing in groups of convenient size (equal to the number of spindles available in the machine) will be more practicable. By actually running the bobbins on a frame, we can observe them for the duration of an entire doff. This is necessary, since, the vibration may be confined to a particular stage of the doff. The percentage of defectives can be estimated by pooling the information at each stage and this can be used to test, whether the value assumed for the process average is correct. The plan thus modified will be as follows :

Nomenclature

N — number of pieces in the lot

$100p$ — process average assumed from previous experience

$100p'$ — allowable percentage of defectives. Also previously fixed.

n — number of pieces in a group

i — serial number of group.

d_i — number of defectives removed in the ith group.

D — the number of defectives that are to be removed to make the lot of acceptable quality. $\Sigma d_i = D$ when inspection terminates.

Procedure

(a) Prepare a chart ; the x-axis to show i the serial number of the group and y axis $(Np - \Sigma d_i)$ the number of defectives remaining in the lot after the ith stage of inspection.

Draw the base line

$y = Np - D = Np'$

For values of $i = 1, 2, \ldots\ldots$

find $(Np - inp) \pm 1.96 \sqrt{inpq}$ and plot these pairs of points against the respective values of i. Join them by smooth lines. These give the limit lines for $(Np - \Sigma d_i)$ on the basis of a process average equal to $100p$.

(b) Take a random sample of size n, and inspect all the bobbins for the duration of a doff, counting d_1 the number of vibrating ones.

(c) Find $(Np - d_1)$ and plot the point on the chart.

(d) If the point falls within the limits, repeat inspection and plot $Np - (d_1 + d_2)$ on the chart.

(e) Repeat (b), (c) and (d) until at some stage.

(1) the point goes below the base line or (2) the point falls outside the limits.

(f) If (1) happens, terminate inspection. In the other case, estimate the process average afresh as. $\hat{p} = \frac{d_i}{in}$ .where i is the serial number of the group inspected last. Draw the new limit lines given by $(N\hat{p} - in\hat{p}) \pm 1.96 \sqrt{in\hat{p}\hat{q}}$, where $\hat{q} = 1 - \hat{p}$ and continue inspection till (1) or (2) happens.

It is to be noted that the minimum and maximum inspection that would be required if the hypothesis that the process average equal to 100p is not rejected are given by the serial numbers of the groups corresponding to the points of intersection (A, B, in the figures) of the limit lines and the base line.

After inspection terminates, whether the hypothesis is rejected, or not, we can give fiducial limits to the quality of the outgoing lot. To get D defectives we inspect, say, i groups or i x n pieces. Then the estimate for p the process average is given by

$$p = \frac{(D-1)}{in-2} \approx \frac{D}{in} \quad \text{since } D \text{ and } in \text{ are very large.}$$

Also an unbiased estimate for the variance of p is given

$$\frac{\hat{p}\,(1-\hat{p})}{(in-2)} \approx \frac{\hat{p}\,(1-\hat{p})}{in} \quad \text{(Anscombe)}$$

Therefore the limits for $(Np-D)$ are given by

$$(N\hat{p}-D) \pm 1.96\sqrt{\frac{N^2}{in}\,\hat{p}\,\hat{q}} \quad \text{where } \hat{p} = \frac{D}{in} \text{ and } \hat{q} = (1-\hat{p})$$

If p and $\hat{p}$ are very close, the limits can be calculated by substituting p for $\hat{p}$.

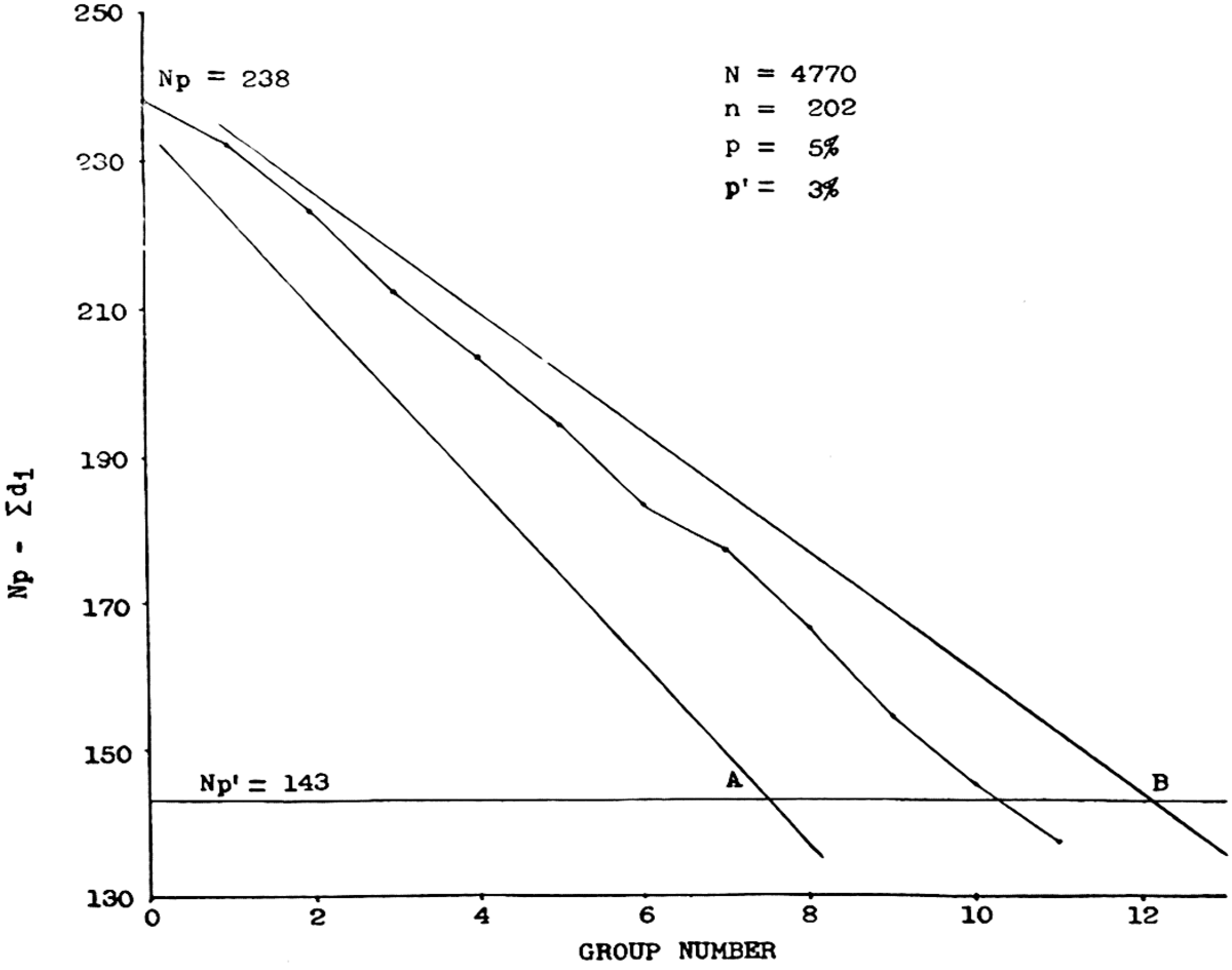
Example 1. The plan was tried out, on an experimental basis, in a local mill. A lot of 4770 bobbins was taken and the proposed method of inspection was applied. The group size was taken to be 202 as there were 202 spindles on one side of a frame. The process average was assumed to be 5% on the basis of previous knowledge. The allowable percentage of defective bobbins, after inspection was tentatively fixed at 3%. The expected number of groups to be examined,

$i = \frac{4770}{202}\,(1\text{-}3/5) = 10$. The adjoining graph is plotted against the serial number, i, of the group. The limits for $(Np - \Sigma d_i)$ are also shown on the graph.

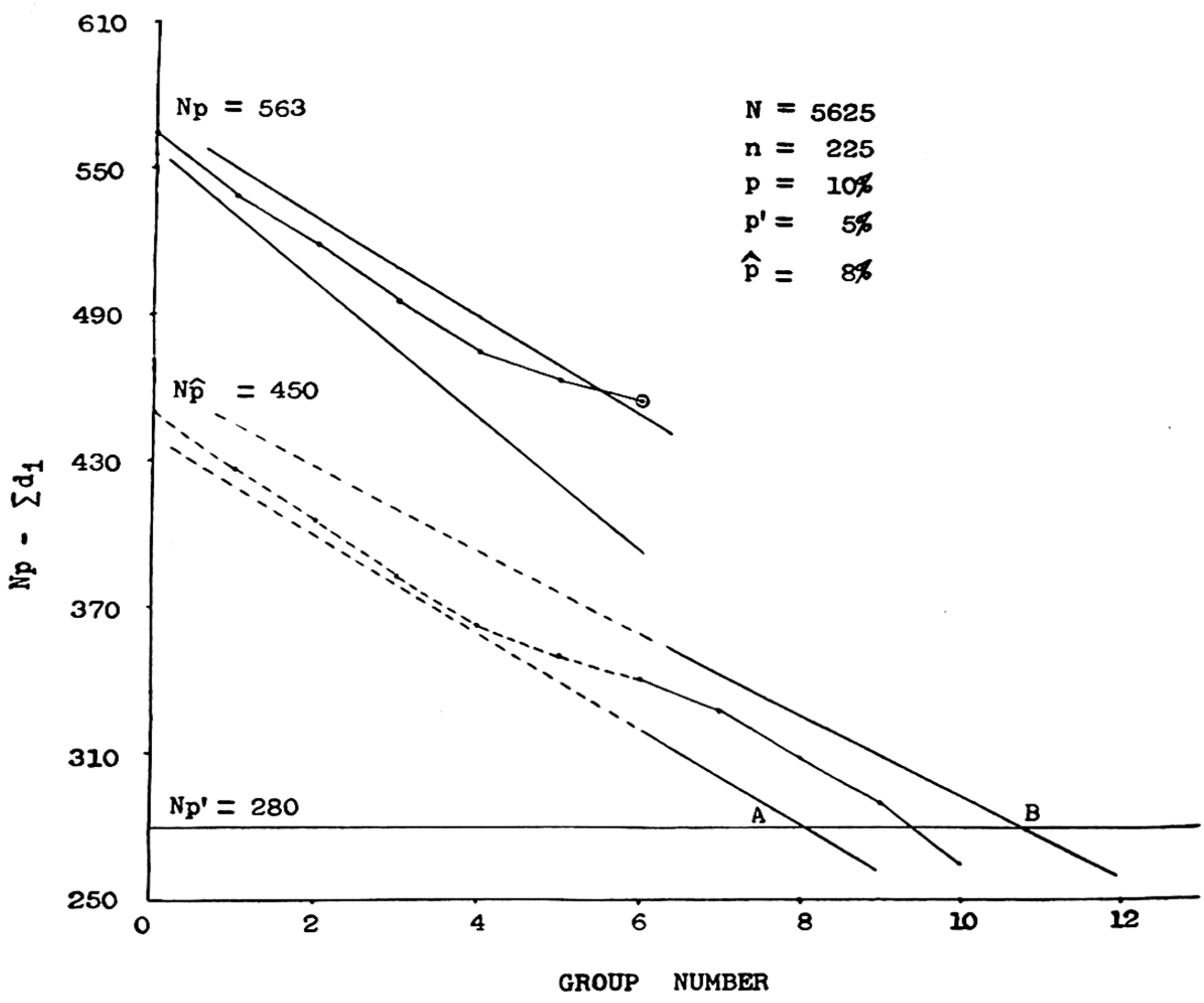
It is seen that inspection has terminated at the 11th stage. The hypothesis that $100p = 5\%$ has not been rejected since all points fall within the limits. The fiducial limits for outgoing quality are (1.53; 3.25). If inspection had been terminated at the 10th stage because at this stage $(Np - \Sigma d_i)$ is 145 which is very close to the required value viz., 143 the limits would have been (1.74 ; 3.54).

Example 2. To study the working of the plan when we start inspection with a wrong estimate of the process average an artificial example has been worked out. The lot size was taken as 5625 and group size 225. The value of *100p* was assumed to be 10% and the allowable limit fixed at 5% Samples were actually constructed for the binomial population with *100p* equal to 8%. At the sixth stage the point goes above the upper limit, showing we have overestimated the value of *100p* %. Estimating the value of *100p* with the information provided by the groups so far inspected, we get about 8%. Making use of this estimate we continue inspection with new limits. Inspection terminates at the 10th stage.

EXAMPLE 1


N = 4770
n = 202
p = 5%
p' = 3%
Np = 238
Np' = 143
A
B
Np - Σd$_1$
250
230
210
190
170
150
130
0
2
4
6
8
10
12
GROUP NUMBER

EXAMPLE 2


610
550
490
430
370
310
250
Np = 563
N$\hat{p}$ = 450
Np' = 280
N = 5625
n = 225
p = 10%
p' = 5%
$\hat{p}$ = 8%
A
B
Np - $\sum d_1$
0
2
4
6
8
10
12
GROUP NUMBER

Instead of a chart showing $(Np - \Sigma d_i)$ against i, one showing d_i itself could as well be used. But on such a chart the line showing the termination of inspection will have to be drawn whenever the hypothesis about process average is rejected.

It remains to point out a few difficulties encountered in using this plan. The disposal of defectives poses a problem. It may not always be possible to send them back to the manufacturer. Our suggestion is to introduce sampling for bobbins used for finer counts and to use the defectives for coarser counts, if possible, because the increase in breaks and loss in strength due to vibration of bobbins in coarser counts is not so appreciable. Taking groups at random is neither very easy. The size of a lot it not always constant and sometimes becomes very small or very big. This can be overcome by either grouping or sub-dividing the lots into suitable sizes.

Another major difficulty is due to the difference in degree of vibration from manufacturer to manufacturer or from time to time for the same manufacturer. This means lots having the same process average of defectives but coming from different manufacturers are not identical in quality. The remedy, though obvious, but difficult to put in practice is to alter the allowable percentages suitably whenever it is found necessary.

But the advantage of the plan is that it does not require a very stable process average, not even lots which are " specific in quality and which commonly retain their identity " (Doge and Roming) ; and in practice neither is obtained.

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A NOTE ON STANDARDISATION OF TEXTILE ACCESSORIES

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The quality of the output is, in Textile Industry, the resultant of the quality of raw material viz., cotton, the skill of the operatives, the effectiveness of the production processes and the standard of the accessories. Attempts have been made by ATIRA towards bettering each of the four elements which affect the quality of the finished product. It is the object of this paper to summarise our ideas on efforts — the approach and the incumbent difficulties — at standardising the accessories that enter a mill. To list a few of the accessories we have the bobbins, the cheese tubes, the shuttles, the buffers, the pickers and so on.

Before actually starting the work of standardisation, it was felt necessary to impress upon the minds of management the necessity of standardisation. Towards this, experiments were conducted taking particular items like bobbins, spindle tapes etc., to assess the exact amount of deterioration with below par accessories in the quality in quantitative terms. Two such typical experiments dealt with vibrating bobbins and bad spindle tapes. It was found that the presence of 10% vibrating bobbins could increase the breakage rate by as much as 30%. Also a low quality tape always leads to a great loss in the shape of excessive soft bobbins and loss in production. Similarly even a minute difference in weight between pickers is believed to result in excessive breakage of materials and lower the loom efficiency and cloth quality.

The above experiments point out unambiguously the necessity of standardisation. Standardisation may be broadly defined as "a sort of formulation perpeting to define or specifying a particular object or procedure with a view to attain accuracy and uniformity in its production and utilisation". Any standardisation starts with laying down specifications and testing procedures.

Specification can be defined as a group of maximum and minimum values of measurement of different characteristics which determine the use requirement of a given product. A standard is then the immediate consequence of standardisation which gives the best working for given conditions. Testing methods are means for verifying whether the specifications are complied with or not.

Now let us consider in details these two aspects. Specifications needs an exact knowledge of the requirements expected out of a product. The requirement may be given in terms of one or more characteristics. Taking for example, the case of bobbins, the length, the inner and outer diameters at either end for different lifts, the shape and the size of the bore, the quality of wood employed, the paint etc. are some of the important characteristics which require specifications. In the case of spindle tapes, the width, elasticity, breaking strength etc., have to be specified. Though, it is in general easy to enumerate the characteristics of a particular product that are important from the point of specifications, the actual giving of limits for the quality measurements is not very easy. This may involve complicated studies. For instance, though, in the case of bobbins, it is obvious that vibration is controlled by some of the characteristics enumerated above, it is very difficult to give exact limits within which these characteristics should lie to keep the vibration in control. Also in the case of tapes it is difficult to give limits within which the elasticity or breaking strength should lie to give satisfactory working. Such experiments designed to correlate the defect and the measurement of these charactersitics have to be taken up in details before attempting to lay down specifications. To this end, ATIRA has started a project. In this project important loom accessories such as shuttles, buffers, pickers and picking bands are considered. The main characteristic under study is the life of these accessories and data are being collected on the life of these accessories of different qualities. The experiments of the type mentioned above may need very complicated instrumentation. Also they are bound to be very time taking. But as a result of such studies one would be able to lay down limits within which the characteristics are expected to lie. In prescribing these limits statistical measures like Variance, Coefficient of Variation would have to be employed to take into consideration the variability of the results obtained by repetitive testing.

Once the specifications are laid down, detailed procedure for testing whether the specifications are met with in a particular instance have to be drawn up. These test procedures have to be, as far as possible, simple and quick. Also the number of items to be inspected from the lot, the characteristics to be taken and the number of observations to be taken for each characteristic have all to be specified. Here Statistical techniques like Sampling Inspection, Testing Hypothesis etc. would be of very great help. One of the major difficulties in laying down testing procedure is the lack of proper instrumentation which could do the work efficiently and in the least time.

All these work needs very complicated organisational set up. Here in India we have made a good beginning with the starting of the Indian Standards Institution in its new building. It has already laid down standards to various items of interest in a majority of the industries. The standards under preparation by the I.S.I., include bobbins, picking bands, shuttles, tapes, check straps etc. But the work I.S.I. can do in this line could be made more fruitful and exhaustive if it is done in collaboration with organisations engaged in research in specific industries.

ISOLATION OF MEANS IN THE ANALYSIS OF VARIANCE

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Introduction

The statistician using the analysis of variance is often confronted with the problem of grouping the individual treatment means into sets of homogeneous groups whenever the F-test leads to the rejection of the null hypothesis that all treatment means are equal. For example, in the textile industry, the statistician after analysing the data for machine (ring frame) difference in lea-strength of yarn, finds by the analysis of variance technique that the average strength is not the same for all machines. However, the spinning master would like to know which of the machines are giving better or worse performance so that he could take corrective action if possible. Nair (1) has given exact test for the most straggling mean for the case of normality. Using an emperical approximation to this Tukey (2) has outlined a simple procedure for classifying the treatment means into homogeneous groups. This procedure is not very satisfactory as it sometimes leads to contradictions. An alternative procedure has been proposed in a later section of this paper. A number of artificial examples, constructed from Mahalanobis' Tables of Random Normal Deviates (3), were analysed by both methods — Tukey's as well as the one suggested by us. The examples indicate that the new procedure gives correct grouping on a smaller sample size than the one outlined by Tukey.

Tukey's Method

50 leas were tested from each of five ring frames for strength. It was found that there were no differences in the count of yarn spun by these frames. The analysis of variance for the data on lea-strengths is given in Table I.

TABLE I

Source	d. f.	s. s.	Mean square
Between frames	4	529.0	132.25
Within Frames	245	10035.2	40.96
Total	249	10564.2	

The average strength of all the frames is not the same as $F = \frac{132.25}{40.96} = 3.23$ on $\nu_1 = 4$ and $\nu_2 = 245$ degrees of freedom is significant at the 5% level. The problem now is to classiify the five ring frames into homogeneous groups. This can be done by the following procedure suggested by Tukey.

Step 1 : Choose a level of significance. Let it be 5%.

Step 2 : Calculate the critical difference for this level.

$$\text{Critical difference} = \sqrt{s^2_e\ (2/n)} \times 5\% \text{ value of } t \text{ on 245 d.f.}$$

$$= \sqrt{40.96 \times \frac{2}{50}} \times 1.97$$

$$= 2.5$$

Step 3 : Arrange the means in ascending or descending order and consider any gap longer than the critical difference as a group boundary. If no group contains more than two means the process terminates.

Arranged in ascending order the means of the frames are

Frame No.	4	2	1	5	3
Mean	79.8	80.5	82.0	83.2	83.5

No difference between adjacent means exceeds the critical difference.

Step 4 : In each group of 3 or more means find the grand mean, the most straggling mean and the difference of these two divided by the standard error of a single mean s_m. Convert the ratios into approximate unit normal deviates by finding

$$\frac{\left|\frac{m - \bar{m}}{s_m}\right| - \frac{6}{5}\log_{10}^{k}}{3\left(\frac{1}{4} + \frac{1}{\nu}\right)}, \quad (k > 3 \text{ means in the group})$$

$$\frac{\left|\frac{m - \bar{m}}{s_m}\right| - \frac{1}{2}}{3\left(\frac{1}{4} + \frac{1}{\nu}\right)}, \quad (3 \text{ means in the group});$$

where $\bar{m}$ is the grand mean of the group,

m is the most straggling mean of the group,

s_m is the standard error of a single mean,

ν is the degrees of freedom for error sum of squares,

and k is the group size.

Separate off any straggling mean for which this is significant at the two sided significance level for the normal.

For our example $\bar{m} = 81.8$, $s_m = 0.91$, $\nu = 245$ and $k = 5$. The value of approximate normal deviate is 1.78. This is not significant as it is less than 1.96, the 5% value of unit normal deviate. Hence we cannot isolate the straggling mean.

Step 5: If step 4 changed any group, repeat the process until no further means are separated from the old groups. The means separated off from one side of a group form a sub-group. If there are any sub-groups of three or more when no more means are being separated from groups, apply the same process (steps 4 and 5) to sub-groups. This does not apply to our example as step 4 has not changed the grouping.

Step 6: Calculate the sum of squares of deviations from the group mean and the corresponding mean square for each group or sub-group of 3 or more resulting from step 5.

Using s_m as the denominator, calculate the variance ratio and apply the F-test to each ratio.

For our example this is the same as the original analysis of variance which indicates that the means of five frames are not homogeneous. Thus we find that this method has not been able to classify the means into homogeneous groups. It was thought that this might be due to approximation made use of. In order to verify this the exact test for straggling means given by Nair was used. The resultant groups were

Group	Frames
I	4 and 2
II	1, 3 and 5

The value of F for testing whether the three frames in Group II were homogeneous was not significant. Thus by using the exact test for the most straggling mean it has been possible, in our present example, to classify the means into homogeneous groups. However, this is not always possible as we have come across cases where the F-test indicated that the resultant group of means after applying the exact test for straggling mean and isolating significantly straggling means, if any, was not homogeneous.

As either Tukey's method involving an approximation of the studentised extreme deviate to the unit normal deviate or Nair's method have not been effective in classifying the means into homogeneous groups, an alternative method has been outlined in the next section.

Suggested Procedure

An alternative procedure for classifying the means into homogeneous groups, proposed by us, is illustrated by applying to the example given in the previous section.

First arrange the means in ascending order. They are

Frame No.	4	2	1	5	3
Mean	79.8	80.5	82.0	83.2	83.5

Test the mean of frame 4 against mean of frame 2 by the t-test with error variance 40.96 on 245 degrees of freedom as an estimate of population variance. The value of t is $\frac{|79.8-80.5|}{\sqrt{40.96 \times 2/50}} = 0.55$ on 245 degrees of freedom and this is not significant at the 5% level. As the two means are not significantly different pool them to get a better estimate of the mean of the common population and test the pooled mean 80.2 of the frames 4 and 2 against the mean of frame 1 using the same estimate of variance. The value of t is $\frac{|80{\cdot}2 - 82{\cdot}0|}{\sqrt{40.96\left(\frac{1}{100}+\frac{1}{50}\right)}} = 1.62$ on 245 degrees of freedom and is not significant at the 5% level. As this is not significant we pool the means of frames 1, 2 and 4 and test against that of frame 5. The value of t is $\frac{|80.8 - 83.2|}{\sqrt{40.96\left(\frac{1}{150}+\frac{1}{50}\right)}} = 2.30$ on 245 degrees of freedom and is significant at the 5% level. Hence frames 1, 2 and 4 form a group.

Now test the mean of frame 5 against that of frame 3 by a similar procedure. The value of t is $\frac{|83{\cdot}5 - 83{\cdot}2|}{\sqrt{40.96 \times 2/50}} = 0.2$ on 245 degrees of freedom which is not significant at 5% level, indicating that frames 3 and 5 form a homogeneous group. The resultant groups are as follows.

Group	Frames
I	1, 2 and 4
II	3 and 5

Now arranging the means in descending order and proceeding on similar lines the groups are

Group	Frames
I	2 and 4
II	1, 3 and 5

Comparing the results of tests performed on ascending and descending orders we find that in both the methods frames 3 and 5 form one group and frames 2 and 4 form another group. Frame 1 is grouped with 2 and 4 in the ascending order tests and with 3 and 5 in the descending order tests. In such cases since frame 1 has been not uniquely classified into one group by both these methods we say that frame 1 forms a group by itself and lies between 2, 4 and 3, 5.

Thus there are three groups as indicated below.

Group	Frame	Mean
I	4	79.8
	2	80.5
II	1	82.0
III	5	83.2
	3	83.5

This grouping appears more convincing to the technicians than the one given by Nair's method.

Accuracy of the Method

In order to study emperically the efficiency of the procedure outlined by us several artificial examples were constructed and analysed by both methods — Tukey's as well as the one suggested by us.

In all four artificial examples were constructed by taking random normal deviates from Mahalanobis' Tables (3).

In the first example 6 samples each of size 40 were taken. Out of these six, two were from normal population with mean 55, two with mean 56 and remaining two with mean 57. The common standard deviation for all the samples was 2.8. The group means and standard deviations were chosen such that the critical difference is greater than the difference between the groups as otherwise there is no necessity to use Tukey's method. Later the sample size was increased to 60, 80 and so on. The other three eaxmples were constructed on similar lines the only difference was in the population parameters and the number of samples taken from each population. All samples whose mean or variance differed significantly from the corresponding population values were omitted and fresh samples taken.

The analysis of data of these examples indicated that in all cases the procedure suggested by us gave the correct grouping on a smaller sample size than the one given by Tukey's method. The results are summarised below.

EXAMPLE 1

Population parameters $m = 55$, $\sigma = 2.8$ $m = 56$, $\sigma = 2.8$ $m = 57$, $\sigma = 2.8$.
Sample Nos. 1,2 3,4 5,6

Grouping according to suggested and Tukey's methods.

Sample size	Group number	Suggested	Tukey's	Estimated Mean for sample					
				1	2	3	4	5	6
40	I II III	1,2 3,4,5 6	1,2,3,4 5,6 *	54.66	54.56	55.79	56.10	56.82	57.42
60	I II III	1,2 3,4 5,6	1,2 3,4,5,6 *	54.74	54.65	55.78	56.23	56.89	57.17
80	I II III	1,2 3,4 5,6	1,2 3,4 5,6	54.78	54.76	55.95	55.88	56.91	56.99

* Method fails.

EXAMPLE 2

Population parameters $m = 40$, $\sigma = 2$, $m = 41$, $\sigma = 2$, $m = 42$, $\sigma = 2$.
Sample Nos. 1,2 3,4 5,6

Grouping according to suggested and Tukey's Methods.

Sample size	Group Number	Suggested	Tukey's	Estimated Mean for sample					
				1	2	3	4	5	6
40	I II III	1,2 3,4,5,6	1,2 3,4,5,6	40.23	40.18	40.98	41.29	41.89	41.68
60	I II III	1,2 3,4 5,6	1,2 3,4,6 5	39.97	40.28	40.91	41.03	41.95	41.57
80	I II III	1,2 3,4 5,6	1,2 3,4 5,6	39.87	40.31	40.96	40.99	42.13	41.74

EXAMPLE 3

Population Parameters $m = 63$, $\sigma = 3.2$ $m = 64$, $\sigma = 3.2$ $m = 65$, $\sigma = 3.2$.
Sample Nos. 1,2 3 4,5,6

Grouping according to suggested and Tukey's methods.

Sample size	Group Number	Suggested	Tukey's	Estimated Mean for sample					
				1	2	3	4	5	6
40	I II III	1,2,3 6 4,5	2 1,3,4,5.6	63.71	63.00	63.98	65.30	65.61	64.50
60	I II III	1,2,3 4,5,6	1,2,3 4,5,6	63.31	63.02	63.78	65.38	65.33	64.67
80	I II III	1,2,3 4,5,6	1,2,3 4,5,6	63.54	62.94	63.75	65.26	65.07	64.87
100	I II III	1,2, 3 4,5,6	1,2,3 4,5,6	63.35	62.90	63.86	65.06	64.96	64.89

EXAMPLE 4

Population parameters $m = 69$, $\sigma = 3.5$ $m = 70$, $\sigma = 3.5$ $m = 71$, $\sigma = 3.5$.
Sample Nos. 1,2,3 4 5,6

Grouping according to suggested and Tukey's methods.

Sample size	Group Number	Suggested	Tukey's	Estimated Mean for sample					
				1	2	3	4	5	6
40	I II III	All	All	68.88	69.57	69.36	70.27	70.33	70.50
60	I II III	1,2,3 4 5,6	All*	69.08	69.03	69.30	70.03	70.65	70.38
80	I II III	1,2,3 4 5,6	All*	69.12	69.07	69.18	69.81	70.59	70.52

* Method fails.

Conclusion

In conclusion we wish to point out that the suggested procedure seems to give the correct grouping on a smaller sample size than the one outlined by Tukey. The theoretical basis for the procedure outlined by us is yet to be investigated.

It is to be noted that by repeated testing at the 5% level the first kind of error is not .05 but somewhat higher. This is true even for Tukey's method.

References

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2 Tukey, J. W. (1949). Comparing Individual Means in the Analysis of Variance, Boimetriks 5, 99.

3 Mahalanobis, P. C. and Others (1934). Tables of Random Samples From a Normal Population. Sankhya, 1, 289.

Note

Subsequently this paper was sent to Professor Tukey for his comments. He pointed out that this method gets its extra power because the error rate here is two to three times greater than his. We agree to this, because though our error rate is 5% to begin with, by applying successive tests, the first kind of error is higher than 25%. We are trying to get the power of this test by keeping the same error rate as of Tukey.

THE PROBLEM OF K SAMPLES FOR POISSON POPULATION IN TEXTILE RESEARCH

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ATIRA

Introduction

In textile experiments and investigations it is often necessary to test whether several treatments (say k in number) differ significantly, the characteristic being the end breakage rate in yarn. Generally several observations of equal duration, either in time or space, are taken for each treatment. The data so obtained can be arranged as follows :

Sample No.	Treatment					
	1	2	………	t	………	k
1	x_{11}	x_{21}	………	x_{t1}	………	x_{k1}
2	x_{12}	x_{22}	………	x_{t2}	………	x_{k1}
……	……	……	………		………	……
……	……	……	………		………	……
n	x_{1n}	x_{2n}	………	x_{tn}	………	x_{kn}

where x_{ti} is the number of breaks in the i-th interval for the t-th treatment.

The number of end breaks can be expected to follow the Poisson distribution,[1] so that the probability of the variable for the i-th sample for the t-th treatment taking the value x_{ti} can be assumed to be $e^{-m_{ti}} \dfrac{(m_{ti})^{x_{ti}}}{x_{ti}\,!}$

The problems that can be considered are whether

(a) the whole set of observations can be regarded as one homogeneous group, arising from the same population ;

(b) the end breaks for any treatment vary not more than might be expected due to chance causes ;

(c) end breakage rate is same for different treatments, assuming that within each treatment the end breakage rate is uniform.

Analytically, the problem would be of the form :

(a) the hypothesis H that the whole set of kn observàtions come from the same Poisson population,

$$i.\,e.\ m_{t1} = m_{t2} = \ldots\ldots\ldots\ldots\ldots\ldots = m_{tn} = m_t,\ (\ t\ =\ 1,2,\ldots\ldots\ k\ )$$

$$\text{and } m_1 = m_2 = \ldots\ldots\ldots\ldots\ldots\ldots = m_k$$

(b) the hypothesis H_1 that the variation within treatments is no more than might be due to chance causes,

$$i.e.\ m_{t1} = m_{t2} = \ldots\ldots\ldots\ldots\ldots = m_{tn} = m_t,\ (t = 1,2, \ldots\ldots\ldots k);$$

(c) the hypothesis H_2 that

$$m_1 = m_2 = \ldots\ldots\ldots\ldots\ldots = m_k$$

given that

$$m_{t1} = m_{t2} = \ldots\ldots\ldots = m_{tn} = m_t,\ (t = 1,2, \ldots\ldots\ldots k)$$

The Square Root Transformation and Analysis of Variance

The 'normal' method of analysing such data is to transform the Poisson variate x_{ti} to an approximately normal variate $y_{ti} = \sqrt{x_{ti}}$ using the square root transformation and then to carry out the usual analysis of variance.[2] The analysis of variance will then be as shown in Table I.

TABLE I

Analysis of Variance Table.

Source	d.f.	s.s.
Between treatments	$k - 1$	$\sum\limits_{t}\sum\limits_{i} (\bar{y}_t - \bar{y})^2$
Within treatments	$k(n - 1)$	$\sum\limits_{t}\sum\limits_{i} (y_{ti} - \bar{y}_t)^2$
Total	$kn - 1$	$\sum\limits_{t}\sum\limits_{i} (y_{ti} - \bar{y})^2$

Since y_{ti} is distributed approximately normally with mean $\sqrt{m_{ti}}$ and variance $1/4$, $4\sum\limits_{t}\sum\limits_{i} (y_{ti} - \bar{y})^2$, $4\sum\limits_{t}\sum\limits_{i} (y_{ti} - \bar{y}_t)^2$ and $4\sum\limits_{t}\sum\limits_{i} (y_t - \bar{y})^2$ follow the χ^2 distribution with (kn—1), k(n—1) and (k—1) degrees of freedom under the null hypothesis H, H_1 and H_2 respectively.

In such cases usually H_1 is tested first and if it is not rejected (by the χ^2 test), indicating that the variation of the means within each treatment is not significant, then H_2 is tested for the equality of the treatment effects. The rejection of H_1 has been interpreted to imply that the "prediction formula is not satisfactory" or that "the experimental errors are higher than the Poisson distribution indicates" (possibly because of superimposition of real random fluctuations from time to time as suggested by Tippett[1]) or that both causes are operating (see Cochran[3]).

In textile experiments, however, it is appropriate to interpret the rejection of H_1 not as a failure of the Poisson model, but as a significant shift in the mean of the Poisson variate within each treatment. In other words, we may say that each observation for a single treatment is still a Poisson variate with its own mean. The Physical significance of this interpretation is discussed in a later section. This interpretation leads us to test whether the overall total of the Poisson variates is the same for all treatments.

If it is the same, we can call the treatments as not significanttly different. This we call hypothesis H_3. Analytically it would mean

$$M_1 = M_2 = \dots\dots\dots\dots = M_k = M$$

where, $M_t = \sum_i m_{ti}$

If the significance of H_1 is associated with this interpretation, we can test H_3 by the above analysis of variance table. It can easily be shown that even when H_1 is not true, $4\sum_t\sum_i (\bar{y}_t - \bar{y})^2$ (*i.e* between treatment sum of squares multiplied by 4) has a χ^2 distribution with (k—1) degrees of freedom. If this χ^2 turns out to be insignificant, still we conclude that the treatments do not differ significantly.

It is to be stressed here that the hypothesis H_3 is a narrow hypothesis and it is to be used only when there is a systematic variation between replications, common to all treatments, which will be the case when replications are at different time periods. Of course the analysis of variance also can cope with the situation if the sum of squares due to replications is taken out from the residual. When there is no systematic variation between replications one should test the hypothesis that the overall treatment means do not vary more than one would expect from the variation in the individual means within a treatment. In such a situation only analysis of variance is applicable.*

However, employing the square root transformation and performing the analysis of variance involves the laborious process of copying the square roots of numerable observations. On the other hand, tests based on likelihood ratio criteria (as described in the next section) involve much lighter computation. Further, the latter method has the same accuracy as the "normal" method for all practical purposes.

The Likelihood Ratio Tests for k samples from Poisson Populations

Sukhatme[4] has shown that the likelihood ratio method leads to chi-square tests for the hypothesis H, H_1 and H_2. The test criterion for hypothesis H_3 can be developed on the same lines as for the previous ones. The test statistics thus obtained for the different hypotheses are :

$$H : -2\log\lambda H \sim \chi^2 H = \sum_t\sum_i (x_{ti} - \bar{x})^2 \div \bar{x}$$

$$H_1 : -2\log\lambda H_1 \sim \chi^2 H_1 = \sum_t\sum_i (x_{ti} - \bar{x}_t)^2 \div \bar{x}_t$$

$$H_2 : -2\log\lambda H_2 \sim \chi^2 H_2 = \sum_t\sum_i (\bar{x}_t - \bar{x})^2 \div \bar{x}$$

$$H_3 : -2\log\lambda H_3 \sim \chi^2 H_3 = \sum_t\sum_i (\bar{x}_t - \bar{x})^2 \div \bar{x}$$

as the population mean becomes large.

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* These remarks have been added on a suggestion by Professor M. S. Bartlett.

The above expressions are distributed approximately as χ^2s' with (kn—1), k(n—1), (k—1) degrees of freedom respectively.

It is to be noted that $\log \lambda_H = \log \lambda_{H_1} + \log \lambda_{H_2}$

It may seem curious that $-2\log \lambda_{H_2}$ and $-2\log \lambda_{H_3}$ are the same even though H_3 is a wider hypothesis than H_2. This is due to the fact that in the former hypothesis no constraint is imposed on the means within each treatment, except their additivity to a constant, i.e. in both the hypothesis $\sum_i m_{1i} = \sum_i m_{2i} = \ldots\ldots = \sum_i m_{ki}$ is tested but in H_2 in addition to this a further constraint that $m_{t1} = \ldots = m_{tn}$ $(t = 1,2,\ldots,k)$ is imposed.

Sukhatme[4] has shown that when the population mean is as large as or larger than 3, the above χ^2 forms follow the ordinary χ^2 distribution with good approximation. The square root transformation has a better approximation for smaller values of the population mean. However, Sukhatme in a later paper[5] has shown that even for population mean equal to one, the approximation is satisfactory if the sample size is as large as 15. Hence for practical purposes we can assume the likelihood ratio test as satisfactory as far as accuracy is concerned. This can be achieved either by taking more than 15 observations for each treatment or by increasing the interval of observation so that the average number of breaks will be greater than 2.

*Applications with Discussion**

Example 1. Twenty eight observations on end breaks, each of fifteen minutes duration on 174 spindles of a ring frame for each of three treatments are given in Table II. The treatments were three methods of preparing the ribbon lap fed to the combers.

Treatment A : Card Sliver → Sliver Lap → Ribbon Lap → Comber Sliver.

Treatment B : Card Sliver → Drawing Sliver from reversed Card Cans → Sliver Lap → Ribbon Lap → Comber Sliver.

Treatment C : Card Sliver → Drawing Sliver → Sliver Lap → Ribbon Lap → Comber Sliver.

After combing the material was processed in the usual sequence upto ring spinning.

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* The data presented here are used to illustrate the Statistical technique; no conclusions relating to technical matters or the effects of treatments mentioned incidentally can be drawn from them.

TABLE II

Treatments					
A		B		C	
4	7	4	6	4	4
5	8	4	4	6	6
6	4	5	2	7	8
3	6	1	9	5	5
8	13	8	4	2	4
7	7	6	4	8	5
8	9	7	4	9	8
4	6	5	3	3	7
5	4	6	5	2	7
3	7	7	10	10	5
3	9	5	4	6	1
8	14	5	5	2	3
3	10	10	7	9	6
5		7		2	
4		5		6	

$\chi^2 H = 91.68$ on 83 degrees of freedom.

[$\chi^2 H_1 = 87.28$ on 81 degrees of freedom and $\chi^2 H_2 = 3.64$ on 2 degrees of **freedom.]**

Since $\chi^2 H$ is not significant there is no evidence to reject the hypothesis that the whole set of observations come from the same Poisson population.

Example 2. Table III gives 30 observations on end breaks on 56 spindles in one hour for each of three treatments. The treatments were the same as in Example 1, but the experiment was conducted in a different mill on a different count.

TABLE III

Treatments					
A		B		C	
11	11	6	11	22	13
13	9	11	3	22	11
7	15	12	8	18	4
10	7	7	7	9	6
3	4	16	8	3	3
11	17	18	17	15	15
19	12	11	9	11	7
7	19	8	12	9	7
8	16	8	9	10	9
4	2	1	4	8	1
9	14	16	6	12	11
10	13	14	9	17	21
10	17	14	10	8	7
8	9	10	13	8	5
5	6	2	6	3	5

$\chi^2 H = 215.89$ on 89 d.f. is significant at the 1% level.

As the observed value of χ^2 is significant the null hypothesis that the whole set of observations come from some common Poisson population is rejected. Now it is to be seen whether

(i) the observations are homogeneous within each treatment i.e. they come from the same Poisson population ;

(ii) there is any difference between treatments.

$\chi^2 H_1 = 214.67$ on 87 d.f. is significant at the 1% level, indicating that the observations are not homogeneous within each treatment. That is the observations within each treatment do not come from the same Poisson population and there is some significant change in the mean of the population from observation to observation.

Now that H_1 is disproved (ii) cannot be tested by testing the hypothesis H_2 since H_2 assumes that H_1 is true. The hypothesis to be tested is H_3. $\chi^2 H_3 = 0.71$ on 2 d.f. is not significant even at the 5% level.

Tests of the three hypothesis H, H_1 and H_3 lead to the conclusion that the entire set of observations within each treatment cannot be said to be homogeneous but the treatment totals are not significantly different and hence the hypothesis of equal effect of the treatments cannot be rejected.

Example 3. Table IV gives the **number** of end breaks in half-an-hour-observations on 100 spindles for each of four types of warp bobbins.

TABLE IV

Observation No.	Type of Bobbin				Observation No.	Type of Bobbin			
	A	B	C	D		A	B	C	D
1	23	17	33	34	17	3	8	9	16
2	20	8	20	31	18	2	9	10	8
3	8	6	5	16	19	4	7	4	11
4	5	3	5	3	20	4	7	1	4
5	4	4	7	6	21	3	1	5	2
6	4	6	6	9	22	3	2	5	6
7	0	3	5	3	23	8	6	1	1
8	6	1	4	1	24	2	2	9	8
9	8	21	14	18	25	5	5	7	7
10	6	12	7	8	26	8	4	9	12
11	2	5	11	5	27	4	6	9	3
12	7	2	2	2	28	2	4	4	3
13	6	7	2	4	29	1	3	5	8
14	8	3	6	2	30	6	4	2	4
15	4	0	1	2	31	7	1	4	1
16	2	4	2	1	32	1	4	1	6

$\chi^2 H_1$ = 683.66 on 124 d.f. being significant at the 1% level, we test H as there appears to be a systematic variation between replications. $\chi^2 H_3$ = 16.87 on 3 d.f. is significant at the 1% level. Since H_3 is not true, it is to be interpreted that the four type of bobbins give significantly different end breaks.

Example 4. Observations on end breaks on 60 spindles during 30 minutes collected for each of two treatments A and B are given in Table V. There were in all 70 observations for treatment A and 68 observations for treatment B. The treatments A and B were the same as in Example 1, but the data refer to a third mill. Treatment C was not tried out in this mill.

TABLE V

A				B			
6	4	5	7	9	4	3	4
7	6	1	2	6	4	3	3
4	5	3	8	4	6	1	5
0	7	4	2	7	9	8	5
2	1	3	4	4	4	3	4
8	5	2	3	6	7	3	7
1	5	3	3	8	2	2	6
4	6	5	3	4	3	5	7
5	5	1	5	3	5	3	
3	1	3	4	2	3	6	
4	2	4		9	8	4	
5	2	4		7	3	3	
5	4	4		4	2	2	
6	1	6		9	4	3	
4	2	8		6	6	4	
9	5	2		7	4	3	
6	3	4		6	8	7	
6	2	2		9	3	8	
5	4	2		7	2	7	
3	8	7		3	3	9	

$\chi^2 H$ = 143.78 on 137 d.f. is not significant at the 5% level. On the result of this test the hypothesis that the whole set of observations come from the same Poisson population cannot be rejected.

$\chi^2 H_1$ = 137.71 on 135 d.f. is not significant at the 5% level, indicating that the hypothesis that within each treatment the observations are homogeneous cannot be rejected. But since $\chi^2 H_2$ = 6.18 on 1 d.f. is significant at the 5% level, the hypothesis that there is no difference between the treatments has to be rejected.

In the beginning one is surprised by this sort of apparent inconsistency. A test of the hypothesis H indicated that the whole set of observations may form one homogeneous group whereas H_2, which is a part of H, indicates that there is a significant difference between the treatments.

After a little consideration, it can be seen that the contradiction occurs because $\chi^2 H$ is less sensitive to difference between means than $\chi^2 H_2$. Since $\chi^2 H \simeq \chi^2 H_1 + \chi^2 H_2$. whenever $\chi^2 H_1$ is not significant its value is small, and usually $\chi^2 H_1$ has very large degrees of freedom compared to those of $\chi^2 H_2$ and as such by adding the two χ^2s the resultant $\chi^2 H$ does not reflect $\chi^2 H_2$ to the same extent as it reflects $\chi^2 H_1$. In essence $\chi^2 H_1$ swamps $\chi^2 H_2$ and $\chi^2 H$ reflects more of $\chi^2 H_1$ whenever $\chi^2 H_2$ has a small value. As the number of observations are increased $\chi^2 H_2$ increases rapidly and $\chi^2 H$ also; that is, the sensitivity of $\chi^2 H$ to detect the differences between means increases with increasing sample size.

As a confirmation of this explanation three artificial samples of size 20 each were taken from three hypothetical Poisson populations with means 2.0, 3.0, and 4.0 respectively and the test applied. Later the sample size was increased to 50 and finally to 100; and the increasing influence of $\chi^2 H_2$ on $\chi^2 H$ was noted for these samples. The results are summarised in Table VI.

TABLE VI

The value of χ^2 under various hypothesis.

Sample Size	$\chi^2 H$	$\chi^2 H_1$	$\chi^2 H_2$
20	65.31 (59)	53.04 (57)	16.00 ** (2)
50	175.82 (149)	146.76 (147)	23.26 ** (2)
100	245.42* (249)	283.01 (297)	64.26 ** (2)

Figures in brackets give the corresponding degrees of freedom.

* indicates significance at the 5% level.

** indicates significance at the 1% level.

It is obvious from this experiment that as n increases $\chi^2 H$ becomes more sensitive to $\chi^2 H_2$. This type of situation is encountered only when H_1 is true.

The other apparent inconsistencies that may be met with are

(i) H_1 not true, but H true, and

(ii) H_1 true, H_2 true but H not true.

These are the only three likely situations because for the same level (less than 10%) of significance (say five per cent) the value of $\chi^2 k(n-1) + \chi^2 (k-1) > \chi^2 (nk-1)$ when $k << n$ and hence the configuration of the acceptance regions will be as shown in Fig. 1. The shaded areas represent where inconsistencies are likely to occur.

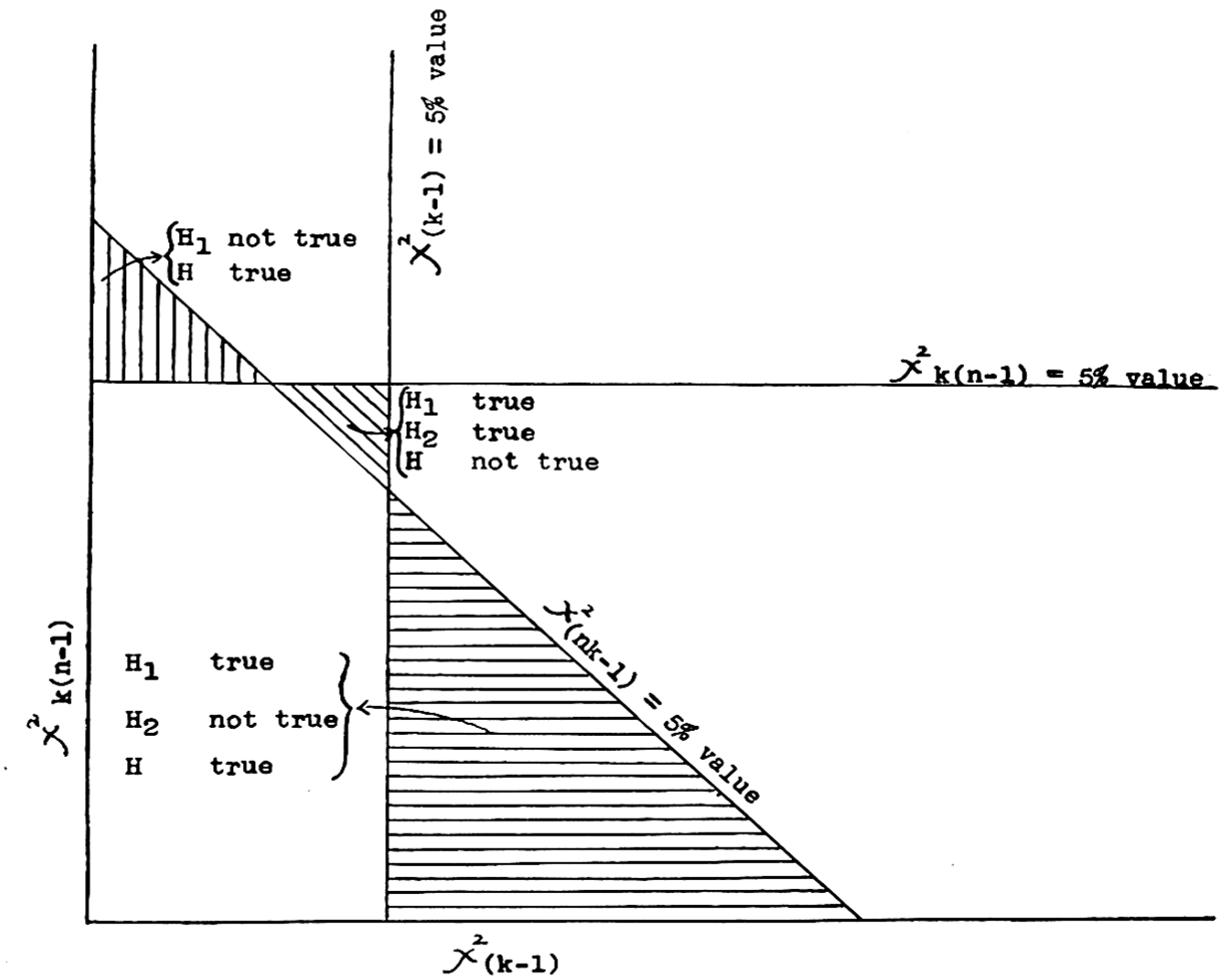
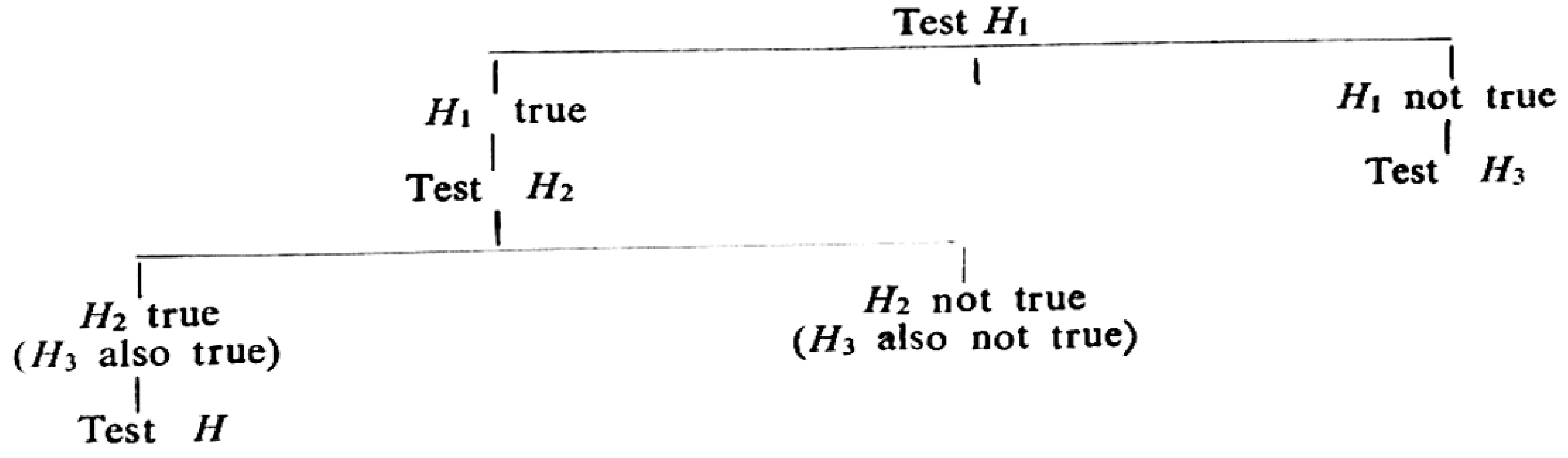


Fig. 1

(It is to be noted that the probability of a point falling in any region is not proportional to its area but has to be worked out from the respective distributions).

Suggestions for Practical Application

In the light of the above discussions the following test procedure is suggested.



In most of the examples in textile research it is only required to know whether there is any significant difference between treatments, irrespective of the shift in the mean within each treatment; and for such cases only H_3 need be tested.

It is generally noticed that H is not true for end breakage data discussed above. That is within the same treatment the observations over a long period are not homogeneous as the mean is constantly changing. It is possibly due to some assignable cause such as change in back stuff relative humidity etc.[1] The exact behaviour of the shift of the population mean within a treatment is yet to be investigated.* In the meanwhile experiments for comparing two or more treatments should be designed in such a way that the disturbing factors can be equalised for all treatments. The number of observations for each treatment should be the same, as otherwise testing of H_3, namely, the treatment totals are the same, has no practical significance.

Confide :ce Limits

When H_1 is not rejected the confidence limits to any single treatment mean, m_t can be derived following a suggestion by E. S. Pearson mentioned by Ricker[7]. For large values of m_t the Poisson distribution can be approximated to the normal with mean m_t and standard deviation $\sqrt{m_t}$, leading to

$$m_t = \bar{x}_t + \frac{l^2 a}{2n} \pm l\, a \sqrt{\frac{l^2 a}{4n^2} + \frac{\bar{x}_t}{n}}$$

where $(1-a)$ is the confidence coefficient and la the corresponding normal deviate.

Alternatively, assuming $\sqrt{\Sigma x_{ti}}$ is distributed approximately normally with mean $\sqrt{nm_t}$ and standard deviation $\frac{1}{2}$ the confidence interval will be $m_t = \bar{x}_t + \frac{l^2 a}{4n} \pm la \sqrt{\frac{\bar{x}_t}{n}}$ where, a and la are as defined above. This method is more appropriate for small vaues of m_t and n. It is however readily seen that both methods will lead to the same interval for larger n. The limits for means of treatment A of Example 4 by both methods are $m_A = (3.6, 4.7)$.

If H_1 is rejected we can still write down the confidence interval for $\sum_i m_{ti}$ as

$\sum_i m_{ti} = \sum_i x_{ti} + \frac{l^2 a}{4} \pm la \sqrt{\Sigma x_{ti}}$ on the assumption that $\sum_i x_{ti}$ follows a Poisson distribution with mean $\sum_i m_{ti}$. The confidence limits thus obtained for Machine 1 of Example 3 are $\sum_i m_{ti} = (165, 219)$. In making use of these limits one has to be careful as the extraneous assignable causes which give rise to the change in the mean within a treatment might be different at different periods. This note of caution applies to the suggeston 1, 3 to make use of the observed variance instead of the expected variance of $\frac{1}{4}$ even when H_1 is not rejected, as the observed variance is likely to change with changing circumstances.

Confidence intervals for the difference between any two treatment means can be derived on similar lines.

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* For example if the mean of a Poisson distribution is not a constant but is shifting according to type III distribution the resultant variation follows a Negative Binomial distribution.

Acknowledgements:

We are grateful to Professor M. S. Bartlett for his valuable suggestions.

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